OPERATING AND SERVICE MANUAL

MODEL 3465A

MULTIMETER

Serial Numbers: 1546A01501 and greater

IMPORTANT NOTICE

This loose leaf manual does not normally require a change sheet. All major change information has been integrated into the manual by page revision. In cases where only minor changes are required, a change sheet may be supplied.

If the Serial Number of your instrument is lower than the one on this title page, the manual contains revisions that do not apply to your instrument. Backdating information given in the manual adapts it to earlier instruments.

Where practical, backdating information is integrated into the text, parts list and schematic diagrams. Backdating changes are denoted by a delta sign. An open delta (Δ) or lettered delta (Δ_A) on a given page, refers to the corresponding backdating note on that page. Backdating changes not integrated into the manual are denoted by a numbered delta (Δ_1) which refers to the corresponding change in the Backdating section (Section VIII).

⚠ This symbol is an international symbol meaning "refer to the Operating and Service Manual." The symbol flags important operating instructions in Figure 3-1 and Paragraphs 3-13, 3-16, 3-21 and 3-27.

WARNING

To prevent potential fire or shock hazard, do not expose equipment to rain or moisture.

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(complete Manual including binder)
-hp- Part No. 03465-90001
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HEWLETT hp PACKARD

CERTIFICATION

Helwett-Packard Company certifies that this instrument met its published specifications at the time of shipment from the factory. Hewlett-Packard Company further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY AND ASSISTANCE

This Hewlett-Packard product is warranted against defects in materials and workmanship for a period of one year from the date of shipment, except that in the case of certain components, if any, listed in Section I of this operating manual, the warranty shall be for the specified period. Hewlett-Packard will, at its option, repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard, and provided the proper preventive maintenance procedures as listed in this manual are followed. Repairs necessitated by misuse of the product are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. HEWLETT-PACKARD IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

If this product is sold as part of a Hewlett-Packard integrated instrument system, the above warranty shall not be applicable, and this product shall be covered only by the system warranty.

Service contracts or customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This section contains general information concerning the -hp- Model 3465A Multimeter. Included is an instrument description, specifications, information about instrument and manual identification, option and accessory information and safety considerations.

1-3. DESCRIPTION.

1-4. The -hp- Model 3465A Multimeter is a 4-1/2 digit, five function digital multimeter. The five functions are dc volts, ac volts, dc current, ac current and ohms. Measurements can be made to four significant digits with a sample rate of 2-1/2 readings per second. Throughout this manual, the 3465A Multimeter will be referred to as Multimeter.

1-5. SPECIFICATIONS.

1-6. Instrument specifications are listed in Table 1-1. These specifications are the performance standards or limits against which the instrument is tested. Any change in the specifications due to manufacturing, design or traceability to the U.S. National Bureau of Standards will be covered by revised pages to this manual. Additional information describing the operating characteristics are not specifications but are supplemental information for the user.

1-7. INSTRUMENT AND MANUAL IDENTIFICATION.

1-8. Hewlett-Packard uses a two-section serial number. The first section (prefix) identifies a series of instruments. The last section (suffix) identifies a particular instrument within the series. If a letter is included with the serial number, it identifies the country where the instrument was manufactured. This manual is kept up–to–date with the instrument at all times by revision. If the serial prefix of your instrument differs from the one on the title page of this manual, refer to Section VIII for backdating information that will adapt this manual to your instrument. All correspondence with Hewlett-Packard should include the complete serial number.

1-9. OPTIONS.

1-10. Multimeter options are available to provide alternate methods of powering the instrument. The standard instrument is powered by rechargeable NiCad batteries or can be powered from an ac source of 86 to 127 V or 172 to 254V, 48 to 66 Hz.

1-11. Option 001.

1-12. Option 001 allows ac line operation only. Power is derived from an ac source of 86 to 127 V or 172 to 254 V, 48 to 66 Hz. Two NiCad Battery Packs can be installed at any time to allow portable operation of the Multimeter.

1-13. Option 002.

1-14. Option 002 is powered by four "D" type dry cell batteries (U2 in Europe). Alternate power can be derived from most Hewlett-Packard hand-held calculator battery chargers such as the Model 82002A Battery Charger/AC Adapter through a special rear panel input connector.

1-15. ACCESSORIES.

1-16. The following accessories are available to extend the usefullness of your Multimeter:

1. Model 11096A RF Probe, 100 kHz to 500 MHz (down 3 dB at 10 kHz and 700 MHz), for use on the 10 V and 100 V ranges in the DCV function only.
2. Model 11002A Test leads, dual banana to dual alligator.
3. Model 11003A test leads, dual banana to probe and alligator.
4. Submodule front handle, -hp- Part No. 5061-2001.
5. Handle Kit (Rack), -hp- Part No. 5061-0088.
6. Rack adapter kit (includes 1/2 module filler), -hp- Part No. 5061-0054.
7. Nickel Cadmium Battery Pack (2 required) -hp- Part No. 00035-60024.
8. Model 82002A Battery Charger/AC Adapter, alternate power (battery elimination) for the Option 002 Multimeter.
9. 11129A Binding Post Kit.

1-17. SAFETY CONSIDERATIONS.

1-18. This operating and service manual contains cautions and warnings alerting the user to hazardous operating and maintenance conditions. This information is flagged by a caution or warning heading and/or the symbol ⚠. The ⚠ symbol appears on the front panel and is an international symbol meaning "refer to the Operating and Service Manual". This symbol flags important operating instructions located in Section III. To ensure the safety of the operating and maintenance personnel and retain the operating condition of the instrument, these instructions must be adhered to.

Table 1-1. Specifications.

DC VOLTMETER

Ranges: 10 mV, 100 mV, 1 V, 10 V, 100 V, 1000 V

Overrange: 100% on all ranges except 1000 V max. on the 1000 V range.

Accuracy: (90 days, + 23 °C ± 5 °C):

RANGE	SPECIFICATION ± (% Reading + % Range)
10 mV	± (0.03 % + 0.02%)
100 mV through 100 V	± (0.02 % + 0.01%)
1000 V	± (0.025% + 0.01%)

Temperature Coefficient (0 °C to 50 °C): ± 0.003% of Reading/ °C

Effective Common-Mode Rejection (with 1 kΩ imbalance in either lead):

AC: > 120 dB at 50/60 Hz ± 0.1%

AC Normal-Mode Rejection:

> 60 dB at 50/60 Hz ± 0.1%

Input Resistance:

10 mV through 1 V ranges: (80% R.H.) $\geqslant 10^{10}$ Ω

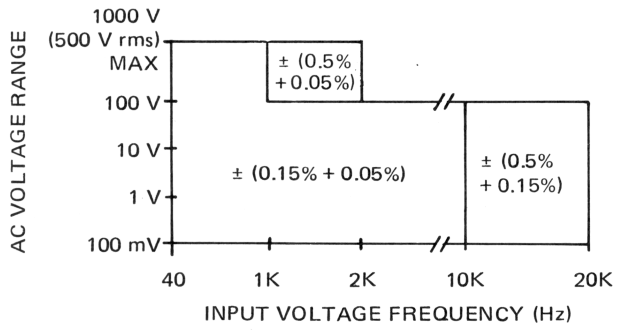
10 V through 1000 V ranges: 10 MΩ ± 1%

AC VOLTMETER

Ranges: 100 mV, 1 V, 10 V, 100 V, 1000 V (500 V Max)

Overrange: 100% on all ranges to 10 kHz decreasing linearly to 0% at 20 kHz. Maximum input voltage on the 1000 V range is 500 V rms.

Accuracy: (90 days, + 23 °C ± 5 °C) ± (% Reading + % Range)



Temperature Coefficient (0°C to 50°C): ± (0.005% of Reading + 0.002% of Range)/°C

Input Impedance: 1 M ± 1% shunted by < 100 pF

DC AMMETER

Ranges: 100 μA, 1 mA, 10 mA, 100 mA, 1000 mA

Overrange: 100% on all ranges

Accuracy: (90 days, + 23 °C ± 5 °C)

RANGE	SPECIFICATION ± (% of Reading + % of Range)
100 μA, 1 mA	± (0.07% + 0.01%)
10 mA	± (0.11% + 0.01%)
100 mA, 1000 mA	± (0.6 % + 0.01%)

Temperature Coefficient (0 °C to 50 °C):

RANGE	SPECIFICATION ± (% of Reading)/ °C
100 μA	± 0.006%
1 mA, 10 mA	± 0.004%
100 mA, 1000 mA	± 0.01 %

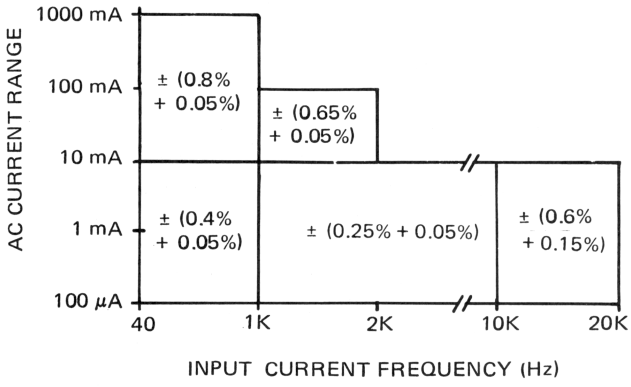
AC AMMETER

Ranges: 100 μA, 1 mA, 10 mA, 100 mA, 1000 mA

Overrange: 100% on all ranges to 10 kHz decreasing linearly to 0% at 20 kHz.

Accuracy: (90 days, + 23 °C ± 5 °C)

± (% of Reading + % of Range)



Temperature Coefficient (0°C to 50°C): ± 0.01% of Reading/°C

OHMMETER

Ranges: 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1000 kΩ, 10 MΩ

Overrange: 100% on all ranges

Accuracy:(90 days, + 23°C ± 5°C)

RANGE	SPECIFICATION ± (% of Reading + % of Range)
100 Ω	± (0.02% + 0.02%)
1 kΩ through 1 MΩ	± (0.02% + 0.01%)
10 MΩ	± (.1% + .01%)

Temperature Coefficient (0 °C to 50 °C):

RANGE	SPECIFICATION ± (% of Reading)/ °C
100 Ω through 1 MΩ	± 0.0015%
10 MΩ	± 0.004 %

Table 1-2. General Information.

Maximum Input Voltages:

Between Input HIGH (V, Ω) and COM:

FUNCTION	MAX VOLTAGE
DC Volts	1000 V (dc + peak ac)
AC Volts	600 V dc; 500 V ac rms; 800 V peak ac
Ohms	350 V (dc + peak ac)

Between AMPS (A), HIGH (V, Ω) and COM terminals and ground:

± 500 V (dc + peak ac)

ACA and DCA Voltage Burden (nominal at full-scale):
1000 m range: < 250 mV
All other ranges: < 125 mV

Reading Rate: 2.5 samples per second

Overload Indication: Display Blanks except for overrange "1" and decimal point (also polarity sign on DCV or DCA FUNCTIONS).

Ohms Terminal Characteristics:

Configuration: 2 wire

Open-circuit voltage: < 5 V max.

Overload protection: 350 V (dc + peak ac)

Nominal current through unknown resistance:

RANGE	CURRENT
100 Ω	1 mA
1 KΩ	1 mA
10 KΩ	10 μA
100 KΩ	10 μA
1000 KΩ	1 μA
10 MΩ	0.1 μA

Power Requirements:

Standard	ac source:	86 to 127 V; 48 to 66 Hz 172 to 254 V; 48 to 66 Hz
	batteries:	2 rechargeable NiCad battery packs
Option 001	ac source:	86 to 127 V; 48 to 66 Hz 172 to 254 V; 48 to 66 Hz
Option 002	batteries:	4 "D" type dry cells (U-2 cells in Europe)
	battery elimination:	Most Hewlett-Packard hand-held calculator chargers such as the Model 82002A Battery Charger/AC Adapter

Environmental Considerations:

Operating temperature: 0°C to 55°C (32°F to 131°F)

Humidity range: 95% at 40°C

Storage temperature: -40°C to +75°C (-40°F to 167°F)

SECTION II
INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains information and instructions for the installation and shipping of the Multimeter. Included are initial inspection procedures, power and grounding requirements, environmental information and instructions for repackaging for shipment.

2-3. INITIAL INSPECTION.

2-4. This instrument was carefully inspected both mechanically and electrically before shipment. It should be free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit, and the electrical performance should be tested using the performance tests outlined in Section V. If there is damage or deficiency, see the warranty inside the front of this manual.

2-5. POWER REQUIREMENTS.

2-6. The Standard and Option 002 Multimeters have an internal battery source. In addition, either Standard or Option 002 instruments can be operated from any ac source of 86 V to 127 V or 172 V to 254 V at 48 Hz to 66 Hz. The Option 002 instrument requires the use of a Hewlett-Packard hand-held calculator Battery Charger/AC Adapter Model 82002A for instrument operation from the ac source.

CAUTION

Verify that the 110 V/220 V Line Voltage Selection switch, located on the rear panel of the Standard, Option 001 Multimeter or the Model 82002A Battery Charger/AC Adapter, is set to the ac source voltage to be used before inserting the power cord and turning the instrument on.

2-7. GROUNDING REQUIREMENTS.

2-8. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. The Standard and Option 001 Multimeters are equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable is the ground wire.

2-9. To preserve the protection feature when operating from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to power line ground.

2-10. ENVIRONMENTAL REQUIREMENTS.

2-11. The Multimeter should not be operated where the ambient temperature exceeds 0°C to 55°C (32°F to 131°F) or stored where the ambient temperature exceeds - 40°C to + 75°C (- 40°F to 167°F).

WARNING

To prevent potential electrical or fire hazard, do not expose equipment to rain or moisture.

2-12. REPACKAGING FOR SHIPMENT.

2-13. The following paragraphs contain a general guide for repackaging the instrument for shipment. Refer to Paragraph 2-14 if the original container is to be used; 2-15 if it is not. If you have any questions, contact your nearest -hp- Sales and Service Office (see back of Manual for office locations).

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished. Include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number and full serial number.

2-14. Place instrument in original container with appropriate packing material and seal well with strong tape or metal bands. If original container is not available, one can be purchased from your nearest -hp- Sales and Service Office.

2-15. If original container is not to be used, proceed as follows:

a. Wrap instrument in heavy paper or plastic before placing in an inner container.

b. Place packing material around all sides of instrument and protect panel face with cardboard strips.

c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

2-16. POWER CORDS AND RECEPTACLES.

2-17. Figure 2-1 illustrates the standard power receptacle (wall outlet) configurations that are used throughout the United States and in other countries. The -hp- part number shown directly above each receptacle drawing is the part number for a Standard or Option 001 Multimeter power cord equipped with the appropriate mating plug for that receptacle. If the appropriate power cord is not included with the instrument, notify the nearest -hp- Sales and Service Office and a replacement cord will be provided. The Multimeter power cord, power input receptacle and mating connectors meet the safety standards set forth by the International Electrotechnical Commission (IEC).

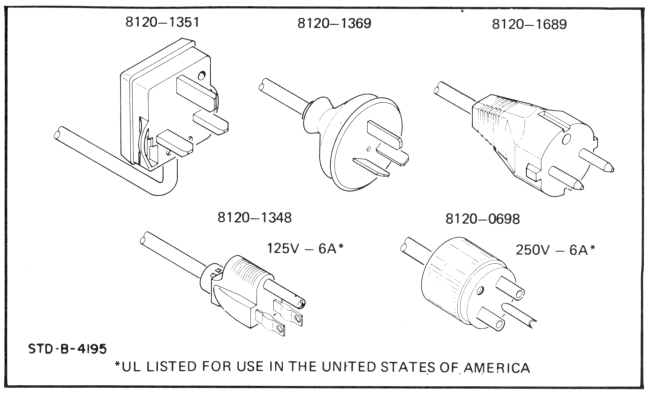


Figure 2-1. Power Receptacles.

SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. This section contains instructions for using the Multimeter for making dc voltage, ac voltage, dc current, ac current and ohms measurements. The section also contains a description of the front and rear panel features.

WARNING

To prevent potential electrical or fire hazard, do not expose the Multimeter or its accessories to rain or moisture.

3-3. Front and Rear Panel Features.

3-4. An illustration and description of the front and rear panels is provided in Figure 3-1. All controls and connectors are identified and briefly described. Some rear panel features are available with certain options only and are identified in the description.

3-5. Turn-on and Warm-up.

3-6. For specified measurement accuracy, allow the instrument to warm-up for at least 10 minutes.

CAUTION

Before operating from an ac source, verify that the 110/220 V line voltage selection switch, located on the rear panel of the Standard and Option 001 Multimeter or the Model 82002A Battery Charger/AC Adapter, is set to the ac source voltage to be used.

3-7. Internal Battery Voltage Measurement and Recharging.

3-8. The Multimeter contains a feature allowing the user to check battery strength to determine the need for battery replacement or recharging. The procedure is to place the Multimeter in the DCV function and depress the 10 megohms range switch. Batteries with full charge will produce a front panel display of approximately .370. If the front panel display is .300 or less, replace Option 002 dry-cell batteries or recharge the Standard Multimeter NiCad batteries. Recharging of the NiCad batteries is performed by operating the Multimeter on an ac source (verify line voltage selection switch is in correct position for source voltage used). Measurements can be made with the Multimeter operated from the ac source during the recharging period.

NOTE

After 14 hours, a completely discharged battery will be fully charged. Shorter charge periods will allow reduced battery operating time. There is no danger of overcharge. For convenience, overnight charging is recommended.

3-9. Low Battery Voltage Detection.

3-10. The Standard and Option 002 Multimeters contain an internal battery source (Standard contains rechargeable NiCads; Option 002 contains "D" cell or "U2" batteries). A battery source safety feature of the Multimeter is a low battery voltage detection circuit which turns the instrument off when battery voltage reaches a low level. This protects against cell reversal of the NiCad batteries. If during operation the display disappears or immediately after turn-on the display appears and disappears after several seconds, low battery voltage is indicated. To verify low battery voltage, the procedure described in the preceding paragraph can be used or verify by placing the OFF/ON switch to OFF and to ON again. The display will appear and again disappear. Operation from an ac line source and recharging of the NiCad batteries is required in a Standard instrument. Replacement of "D" cell or "U2" batteries is required in an Option 002 instrument.

3-11 Overload Indication.

3-12. The Multimeter is capable of displaying up to 100% of range (19999) for all functions and ranges except the 1000 V range in ac or dc volts (see ac and dc voltage measurement paragraphs). In an overload condition where the input exceeds 19999, the last four digits blank and the overrange "1" and decimal point will be displayed. The polarity sign is also displayed in the dc volts and dc current functions in the overload condition.

3-13. AC VOLTAGE MEASUREMENTS.

⚠ **CAUTION**

Maximum input voltage in the ACV FUNCTION is 500 V rms, 800 V peak and 600 V dc. Do not exceed these voltages or damage to the instrument will occur.

3-14. AC VOLTAGE Ranges.

3-15. The ACV FUNCTION has five ranges from 100 mV to 1000 V. Each range (except the 1000 V range) has a 100% overrange capability up to 10 kHz decreasing linearly to 0% at 20 kHz. Maximum input voltage on the 1000 V range is indicated in the AC VOLTAGE MEASUREMENTS caution in Paragraph 3-13.

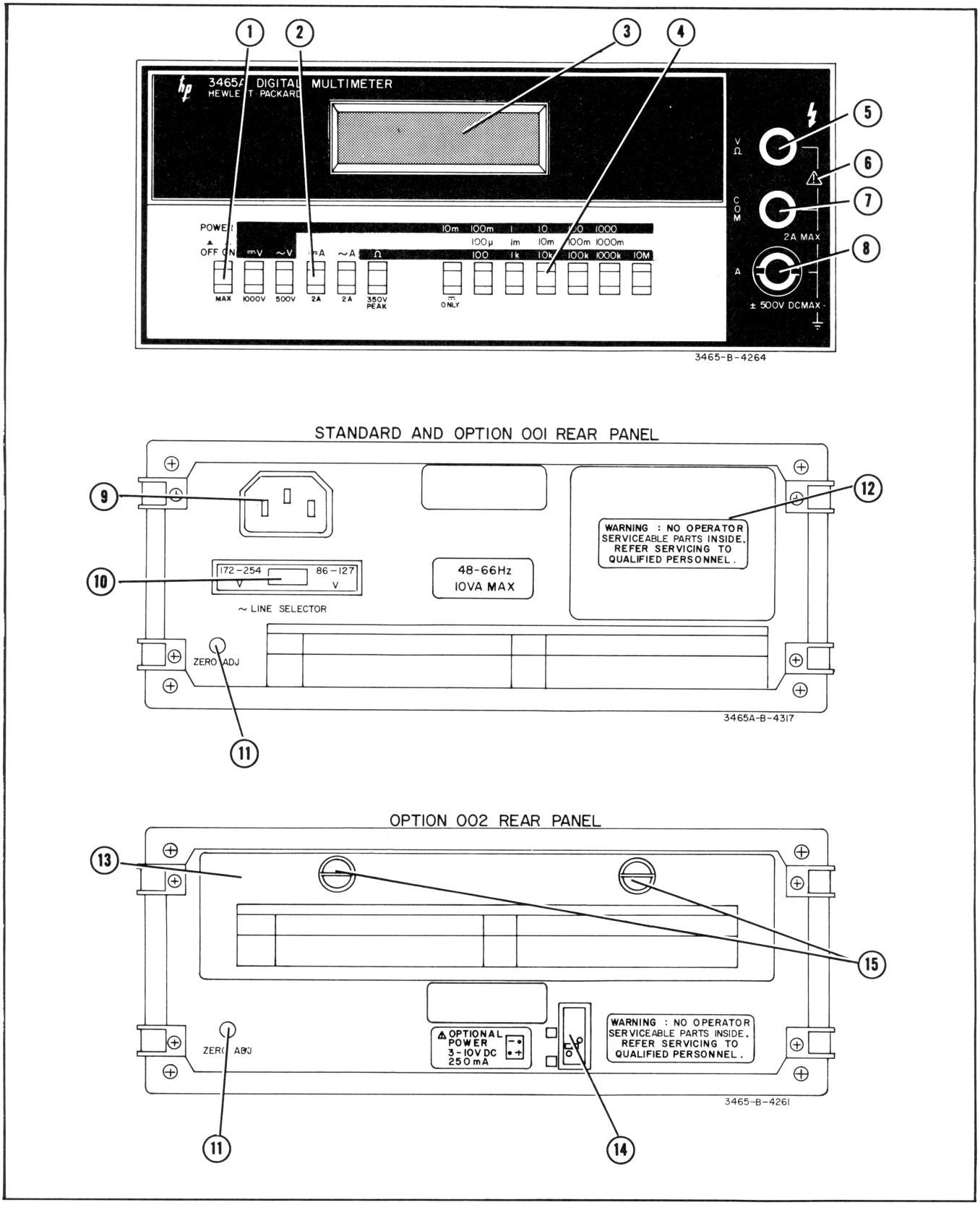


Figure 3-1. Front and Rear Panel Features.

⚠ CAUTION

Do not apply a voltage greater than ± 500 V dc or 500 V peak between any terminal and chassis ground or damage to the instrument will occur.

(1) **OFF/ON Switch.** Pushbutton push on/push off switch.

(2) **FUNCTION Switch.** Function markings are located above each pushbutton switch.
- ⎓ V = DC Volts
- ~V = AC Volts
- ⎓A = DC Amps
- ~A = AC Amps
- Ω = Ohms

(3) **Display.** Indicates the measured value and polarity of dc volts or amps.

(4) **RANGE Switch.** Range markings are located above each pushbutton switch. Color bands identify the range switches associated with each function switch.

(5) **DCV/ACV/OHMS** High input terminal.

(6) ⚠ **Symbol.** This symbol is an international symbol meaning "refer to the Operating and Service Manual". This symbol will appear in this section of the manual flagging operating instruction information.

(7) **COM** input terminal. This terminal is connected to circuit ground for all measurements except ohms. In the ohms function, the COM terminal is disconnected from circuit ground.

(8) **DCA/ACA** High input terminal. 2 Amp fuse located behind removable "A" terminal cap.

(9) **AC** power input connector.

(10) **Line** voltage selection switch.

(11) **ZERO ADJ.** Internal adjustment used to zero the display in the DCV FUNCTION, 10 mV RANGE.

(12) Battery access door (Standard and Option 001).

(13) Battery access door (Option 002 only).

(14) Calculator battery charger (Model 82002A) power input connector (Option 002 only).

(15) Battery access door lock (Option 002 only).

Figure 3-1. Front and Rear Panel Features (cont'd).

3-16. DC VOLTAGE MEASUREMENTS.

⚠ CAUTION

Do not exceed a maximum input voltage of 1000 V dc and peak ac on the 1000 V range or damage to the instrument will occur. There is no overrange capability on the 1000 V range.

3-17. 10 mV Range Zero Adjust.

3-18. When using the Multimeter on the 10 mV range in DC volts, short the input terminals and zero the Multimeter display with the rear panel ZERO ADJ control (see Figure 3-1). The display should indicate 0.000 before proceeding with measurements.

3-19. DC Voltage Ranges.

3-20. DC Voltage measurements can be made from 10 mV to 1000 V full-range. Each range has 100% overrange capability except the 1000 V range which has a maximum input of 1000 V dc and peak ac (see DC Voltage measurements caution in Paragraph 3-16).

3-21. CURRENT MEASUREMENTS.

⚠ CAUTION

Do not exceed a maximum dc or ac rms input current of 2 A or the amps fuse, located directly behind the "A" terminal, will open. See the following paragraph for replacement instructions.

3-22. The Multimeter is protected from the application of excessive current by a 2 A fuse located directly behind the front panel "A" terminal. If it is necessary to replace this fuse, use the side slots on the "A" terminal to rotate the terminal. The terminal and fuse will protrude from the front panel. Remove the terminal and fuse, replace fuse with a 2 A rated fuse as listed in Table 6-3 Miscellaneous Parts General, and designated F1.

3-23. AC Current Ranges.

3-24. AC current measurements can be made over a frequency of 40 Hz to 20 kHz. There are five current ranges from 100 μA to 1000 mA with 100% overrange up to 10 kHz decreasing linearly to 0% at 20 kHz. (See current measurements Caution in Paragraph 3-21.)

3-25. DC Current Ranges.

3-26. DC Current measurements can be made on five current ranges from 100 μA to 1000 mA. Each range has a 100% overrange capability (see current measurements caution in Paragraph 3-21).

3-27. OHMS MEASUREMENTS.

CAUTION

Do not apply voltage greater than ± 350 V dc + Peak AC between the ohms and common input terminals in the ohms function or damage to the instrument will occur.

3-28. Ohmmeter Ranges.

3-29. Resistance measurements can be made on six ranges from 100 ohms to 10 megohms each with a 100% overrange capability. Both input terminals (Ω and COM) are floating with respect to circuit ground.

3-30. Ohmmeter Reference Current.

3-31. The ohmmeter reference current through the unknown resistance for each range is shown in Table 3-1.

Table 3-1. Ohmmeter Current Through Unknown.

Range	Current Through Unknown
100 Ω	1 mA
1 KΩ	1 mA
10 KΩ	10 μA
100 KΩ	10 μA
1000 KΩ	1 μA
10 MΩ	0.1 μA

Maximum open-circuit voltage at the ohms input terminals is less than 5 V.

SECTION IV
THEORY OF OPERATION

4-1. INTRODUCTION.

4-2. This section contains the theory of operation for the Multimeter. The information is divided into two parts:

1. Simplified Theory
2. Detailed Theory

The simplified theory provides an overview of the operation of each section in the Multimeter while the detailed theory describes the circuit operation of each section.

4-3. Description.

4-4. The Multimeter is a five-function, 4-1/2 digit multimeter with 100% overrange capability on all ranges except the 1000 V range. The five functions measured are dc volts, ac volts, dc current, ac current and ohms. The dual-slope integration technique is used for measurements. This technique charges an integrator for a fixed length of time, to a voltage proportional to the input signal, then discharges the integrator at a fixed rate determined by a known reference voltage. The measurement display is determined by the discharge time of the integrator, which is proportional to the input signal.

4-5. Figure 4-1, Basic Block Diagram and Measurement Sequence, illustrates the major functional blocks of the Multimeter. The illustration of the measurement sequence shows the integrator output for each interval of a measurement cycle. This diagram is to supplement the functional block diagram for the simplified theory discussion.

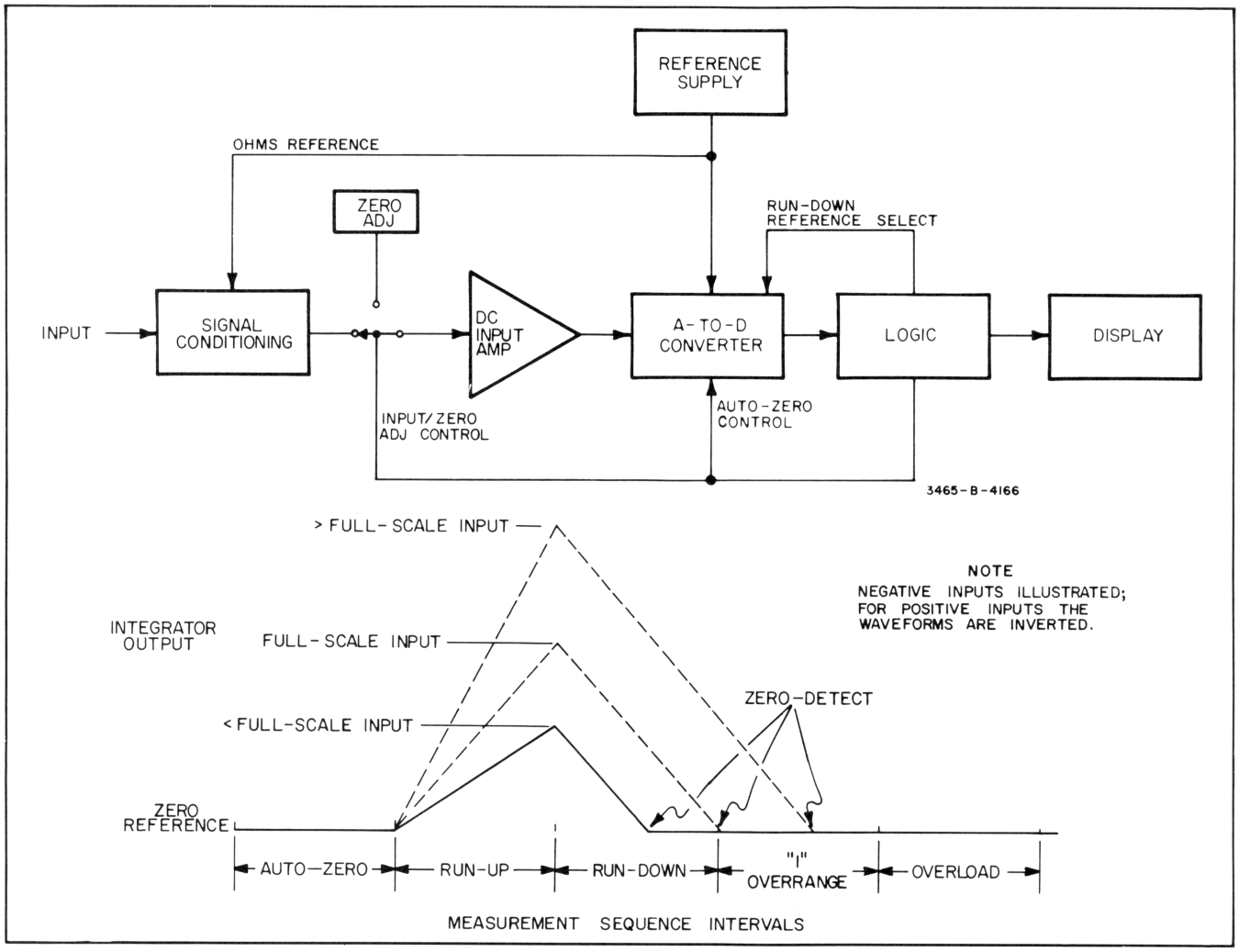


Figure 4-1. Basic Block Diagram and Measurement Sequence.

4-6. SIMPLIFIED THEORY.

4-7. A simplified theory of operation of the Multimeter is presented in the following paragraphs. The simplified theory describes each section of the functional block diagram, Figure 7-1. These sections are the signal conditioning section, analog–to–digital section, logic section and the display section. Also presented is a simplified description of the power supply. Refer to Figure 7-1, Functional Block Diagram, and Figure 4-1, Basic Block Diagram and Measurement Sequence, for this discussion.

4-8. Signal Conditioning.

4-9. Signal conditioning consists of attenuating and/or converting the input signal to a dc voltage within the working limits of the input amplifier. For full-scale inputs, this voltage can vary from 10 mV dc to 1 V dc depending on the function and range.

4-10. The signal conditioning section consists of current shunts, an input attenuator, ohms converter and an ac–to–dc converter. The output from the signal conditioning section is applied to the input amplifier during the run–up interval of the measurement sequence. The Input Amplifier Gain Table located on Figure 7-3 indicates the full-scale input level applied to the input amplifier for each function and range. This signal is the output of the signal conditioning section.

4-11. Ohms Converter. The ohms converter is a high gain integrating amplifier. A simplified diagram of the ohms converter is presented in Figure 4-2. The blocks of the ohms converter are the integrating amplifier, protection diodes, over-voltage protection circuit and the overload loop. An integrating amplifier is used because this type of amplifier is less susceptible to oscillations. The protection diodes clamp the HI terminal to a voltage of about + 1.2 V in the positive direction or - .7 V in the negative direction. With the HI terminal clamped, protection against excessive voltages applied to the ohms terminals is provided by an over-voltage protection circuit located between the ohms amplifier and the LOW terminal. For excessive voltages, this circuit isolates the LOW terminal from the ohms amplifier.

4-12. Figure 4-2 shows two outputs of the ohms converter being applied to the input amplifier. The ohms output is the ohms converter measurement signal and the auto-zero output is the ohms amplifier dc offset signal which is called the auto-zero (AZ) signal. This AZ signal is applied to the input amplifier during the auto-zero interval of the measurement sequence and establishes the reference for the analog–to–digital converter. An AZ signal greater than ± 1 mV causes the instrument readings to be invalid. This condition (AZ signal $> \pm 1$ mV) is present when the unknown resistance, R_x, is removed and an open loop is present on the ohms amplifier. To maintain the AZ signal at $< \pm 1$ mV when an open loop is present, an overload feedback circuit is used.

4-13. The ohms output, (LO terminal of the ohms converter) is applied to the input amplifier. This output is a dc voltage, the level of which is dependent on the ratio of the unknown resistance, R_x, to the variable resistance, 10^n, and the ohms reference supply. The variable resistance, 10^n, is a resistor string located in the precision resistor pack R75. The value of 10^n is selected by the range switches shorting those resistors in the string that are not required. The value of 10^n can range from 10 kΩ to 10 MΩ. A discussion of the precision resistor pack R75 can be found in the detailed theory.

4-14. The formula for the ohms converter output voltage is:

$$\text{Ohms Output} = -\left[\frac{R_x}{10^n}\right] \quad \text{Reference Supply Voltage} + V_{offset}$$

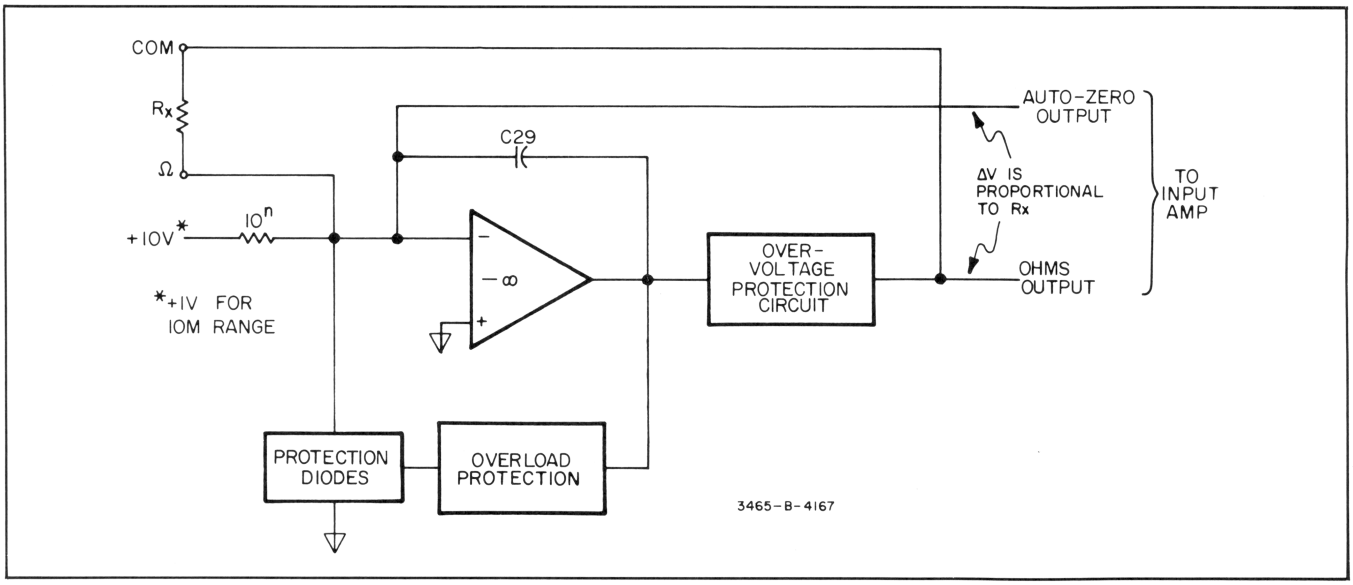


Figure 4-2. Simplified Diagram, Ohms Converter.

The reference supply is + 10 V for all ranges except the 10 M range. For this range the reference supply is + 1 V. The full-scale output of the ohms converter is 1 V dc. On the 10 M range with a R_x of 10 MΩ (full-scale), an output of 1 V dc is needed. From the formula for the ohms output, it can be seen that 10^n would have to equal 100 MΩ. Since the range of 10^n is 10 kΩ to 10 MΩ, a 10^n of 10 MΩ combined with a reference supply of 1 V provides the desired 1 V dc full-scale ohms converter output.

4-15. AC–DC Converter. The ac–dc converter is an average responding ac converter. It measures the average value of a sine wave and multiplies this by a fixed scale factor to convert it to an rms value. The output of the converter is a dc voltage equal to the rms value of the sine wave.

4-16. Figure 4-3 is a block diagram of the ac - dc converter. The blocks consist of an impedance converter, an ac converter and a filter. The impedance converter has a high input impedance to prevent loading of the input signal. It also provides the gain necessary to drive the ac converter. An impedance converter gain of unity, 9.964 or 10 is selected by the function and range switching. The gain of 9.964 is used with the ACI function and the gain of 10 is used with the 100 mV, .1 mA, 100 Ω and 10 V, 10 mA, 10 kΩ ranges.

4-17. The ac converter amplifies the signal from the impedance converter by the scale factor. This converts the average value of the sine wave to the rms value. Half-wave rectification of the sine wave is also performed by the ac converter. This rectified signal is filtered to provide the proportional dc output which is applied to the analog–to–digital converter.

4-18. Analog–to–Digital (A–D) Converter.

4-19. The A–D converter block is comprised of an input amplifier, reference supply, integrator, slope amplifier, comparator and auto-zero circuit. It makes an analog–to–digital conversion using the dual-slope integrating technique. Four control state signals from the logic section (IO, IZ, I1 and I2) regulate the measurement sequence. IO and IZ regulate the input amplifier and auto-zero switching respectively while I1 and I2 select the reference supply required during the run-down interval.

4-20. Input Amplifier. The first stage of the A–D converter is the input amplifier. During the run-up interval of the measurement sequence, control state signal IO switches the output of the signal conditioning block to the input amplifier. The output of the signal conditioning block is a dc voltage which varies between 10 mV and 1 V for full-scale inputs, depending on the function and range selected. The gain of the input amplifier is adjusted by the function and range switching to provide an output of 1 V dc for any full-scale input signal. See Input Amplifier Gain Table on Figure 7-3.

4-21. Reference Supply. The A–D converter uses a monopolar reference supply of + 10 V. A reference voltage is applied to the integrator during the run-down interval to discharge the integrating capacitor. Since the discharge rate is constant, the time required for the integrator to reach a zero reference is proportional to the input signal. This time period is the run-down interval and is processed to determine the display. A positive and negative reference voltage is required since the input signal can be either polarity. A detailed discussion of the operation of the monopolar reference supply can be found in the detailed theory.

4-22. Integrator. The integrator output is a result of a current summation at the integrator summing junction (inverting input). A positive current summation (current flowing into the integrator input) will cause the integrator to ramp negative. A negative current summation (current flowing out of the integrator input) will cause the integrator to ramp positive. The integrator sums currents from the input amplifier, reference supply, - 7 V supply and the auto-zero loop.

4-23. Slope Amplifier. Following the integrator is a X4000 amplifier. This amplifier is divided into two stages; the first with a gain of 40 and the second with a gain of 100. The slope amplifier amplifies the integrator output to provide a more vertical crossing of this output with the reference level. This provides greater accuracy of the voltage–to–time conversion during the run-down interval.

4-24. Comparator. The comparator provides two logic outputs; a high output of 0 V or a low output of - 7 V. The comparator output is high when the integrator output is greater than the reference level. The comparator is low when the integrator output is less than the reference level.

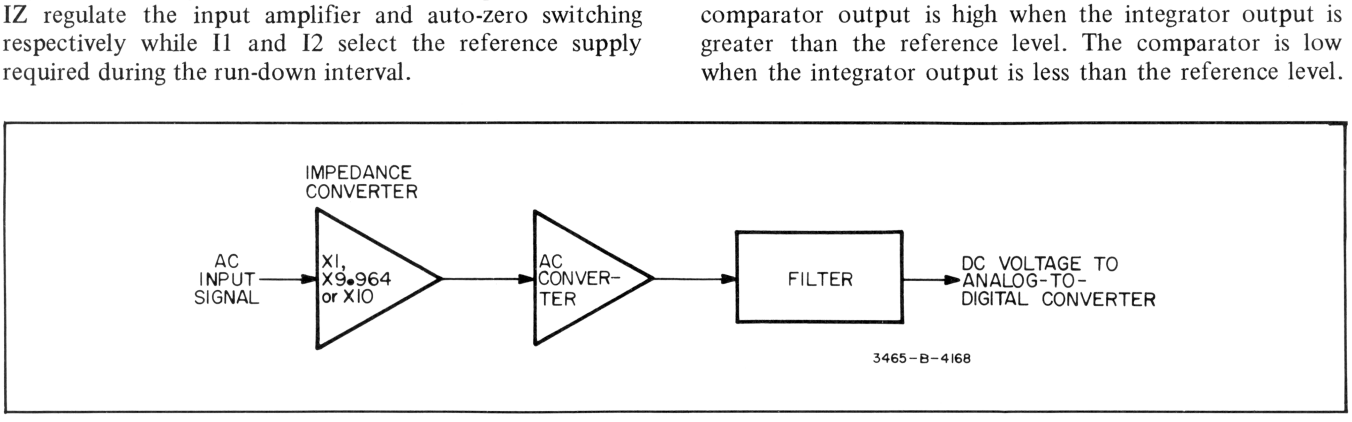


Figure 4-3. Block Diagram, AC–to–DC Converter.

This logic level is sensed by the logic section to determine polarity and zero-detect.

4-25. Auto-Zero Circuit. During the measurement sequence, the auto-zero loop is closed except for the run-up and run-down intervals. This loop includes the slope amplifier and the integrator but does not physically include the input amplifier although the loop does compensate for the input amplifier offset. When the auto-zero loop is closed, the input of the input amplifier is grounded. If the summation of currents at the integrator summing junction is not zero, the integrator begins to ramp up for a negative summation or ramp down for a positive summation. The integrator output is applied through the X4000 slope amplifier to the auto-zero capacitor, C4. The voltage on the auto-zero capacitor causes a current to flow at the summing junction that returns the summation to zero. This auto-zero configuration compensates for the analog offset of the input amplifier and integrator by providing a current at the summing junction that cancels the currents resulting from the offset.

4-26. Logic Section.

4-27. The Logic Section is comprised of combinational and state logic. This section processes the comparator output to determine the polarity of the input signal and to make a voltage–to–time conversion of the input signal. Time accumulated during the conversion is proportional to the input signal and is stored. The display is derived from this accumulated time. A voltage–to–time conversion with the accumulated time being stored occurs once each measurement sequence.

4-28. Seven blocks make up the logic section. These blocks are:

1. Clock
2. State Clock
3. Polarity and Zero Detect
4. Data Transfer and Reset
5. Control State Counter
6. Control State Decode
7. Data Accumulator

The HIGH and LOW logic levels used in the logic section are 0 V and - 7 V respectively. The following discussion describes the basic operation of the logic section.

4-29. Clock and State Clock. The timing of the logic section is derived from the clock circuit. The clock operates at 100 kHz and is crystal-controlled. A state clock, driven by the clock output and the count extend line from the data accumulator, drives the control state counter to initiate each measurement interval.

4-30. Polarity and Zero Detect. The polarity and zero-detect circuit monitors the comparator output. The state of this output at the beginning of the run-down interval determines the polarity of the input signal. Zero-detect is determined at the point the comparator output changes states during the run-down, overrange or overflow intervals. If the integrator ramps positive (negative input signal) during run-up, the comparator output goes HIGH and returns to LOW at the zero-detect point. If the integrator ramps negative (positive input signal) during run-up, the comparator output goes low and returns to high at the zero-detect point. These comparator output logic states are stored in a D flip–flop. At the beginning of the run-down interval, this state identifies the polarity of the input signal. The outputs of the D flip–flop provide the signals needed to select the correct polarity display and the correct reference supply signal (I1, I2) during the run-down interval. An EXCLUSIVE OR and latch processes the comparator output to provide the zero-detect signal.

4-31. Data Transfer and Reset. The data transfer and reset circuits provide logic signals to the data accumulator required to load the storage latches and reset the decade counters. A detailed description of the data accumulator is provided in the detailed theory section. While the $\overline{\text{TXFR}}$ input of the data accumulator is low, data in the decade counters is transferred to the static storage latches. The $\overline{\text{RESET}}$ input resets the decade counters to zero when low. This must occur after the transfer to the storage latches has taken place. To ensure that reset occurs after termination of transfer, an RC delay circuit precedes the reset gates.

4-32. Control State Counter. The control state counter provides the timing for the measurement sequence intervals. The output from the counter establishes the timing of the analog control signals (IZ, IO, I1 and I2) which are applied to the A–D converter. The state clock and reset inputs to the control state counter determine the outputs of the counter.

4-33. Control State Decode. The control state decode converts the polarity, zero-detect and control state counter inputs to the correct analog control signals. These signals, applied to the A–D converter, perform the measurement sequence switching. This switching consists of the input amplifier switch, the auto-zero switch and the reference supply switches.

4-34. Data Accumulator. The data accumulator consists of a counter, data latches, a multiplexer, digit select decoder and output buffers. At the beginning of the Run-Down interval of the measurement sequence, the data accumulator begins to count clock pulses until zero-detect occurs. This count is proportional to the input signal and is the time conversion used to generate the display. The digit select decoder scans the display digits from the most significant digit to the least significant digit while the multiplexer provides the corresponding BCD outputs for each digit. A detailed discussion of the data accumulator is presented in the detailed theory.

4-35. Display.

4-36. The multimeter display contains four full digits with an overrange "1", polarity sign and sample rate indicators. All segments and indicators are light-emitting diodes. A BCD–to–seven–segment decoder receives BCD informa-

tion from the data accumulator and applies the seven-segment code to the display drivers. The display drivers apply the seven-segment code to all digits simultaneously. Digit strobe lines activate the digit corresponding to the seven-segment code at that point in time. Scanning of the digits is from the most significant to the least significant digit. To complete the display, the proper decimal point is enabled by range switching.

4-37. Power Supply.

4-38. Figure 4-4 is a block diagram of the power supply. The power supply develops four output voltages from a single dc input voltage (+ VB). This dc input voltage is applied to a dc–to–dc converter which develops output voltages of + 11 V dc and - 7 V dc. A series regulated + 10 V output is developed from the + 11 V converter output. This + 10 V is used as the reference voltage in the A–D converter and to develop the reference current in the ohms converter and as the reference voltage for the converter regulator. The converter regulator controls the converter and regulates the - 7 V and + 11 V outputs of the converter. The fourth voltage (- 12 V) is derived from the - 7 V converter output with a voltage doubler circuit driven by the 100 kHz clock. A discussion of the operation and regulation process of the dc - to - dc converter is presented in the detailed theory.

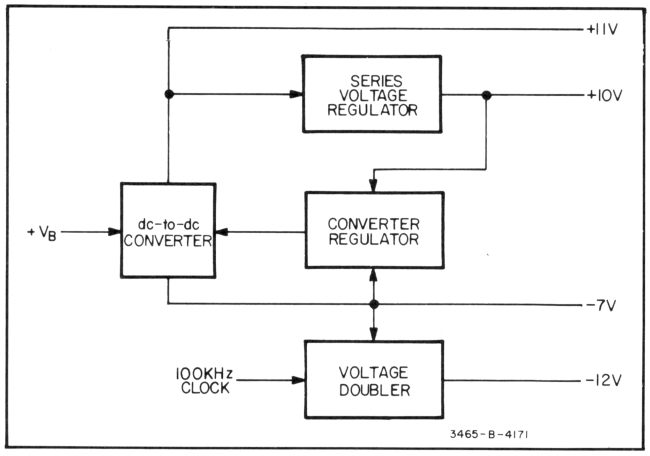


Figure 4-4. Block Diagram, Power Supply.

4-39. DETAILED THEORY.

4-40. This portion of the theory of operation provides a detailed discussion of the circuits in the Multimeter. The circuits described here are the ohms converter, ac–dc converter, monopolar reference supply, data accumulator of the logic section, display and the power supply. A discussion of the precision resistor pack (R75) is also provided. The detailed discussion makes use of the schematics in Section VII.

4-41. Precision Resistor Pack (R75).

4-42. The precision resistor pack, R75, is a laser trimmed substrate providing high precision resistances. A diagram of R75 is shown on Figure 7-2. The input attenuator, power supply, ohms reference supply, A–D reference supply and the input amplifier require highly accurate resistances to maintain the accuracy of the Multimeter. These resistances are part of the resistor pack. The advantage to the resistor pack is high precision resistors and good temperature tracking. As resistance values of the resistor pack change due to temperature changes, the ratio of the resistors remains the same.

4-43. Ohms Converter.

4-44. Refer to Figure 7-2 for this discussion. Both ends of the ohms converter are floating with respect to the instrument ground. The unknown resistor, R_x, becomes the feedback loop of the ohms amplifier. The ratio of R_x to 10^n determines the gain of the ohms amplifier, Q25 and U15. 10^n is a variable resistance between 10 kΩ and 10 MΩ selected by the range switching. The ohms converter input is the reference voltage provided by the ohms reference supply. This reference voltage times the amplifier gain is the ohms converter output supplied to the input amplifier during the run-up interval. Full-scale ohms converter gain and output values are provided in the ohms converter table located on Figure 7-2.

4-45. The HI terminal of the ohms converter is connected to the reference supply through 10^n of the resistor pack R75. The HI terminal is clamped by protection diodes CR15 and CR25 to prevent the destruction of FET Q25 and R75 by the application of large voltages. These diodes clamp the HI terminal to about + 1.2 V positive or - 0.7 V negative.

4-46. With the HI terminal clamped, over-voltage protection must be provided to protect the ohms amplifier from excess voltage. The over-voltage protection circuit is located between the ohms amplifier and the LO terminal and is shown in Figure 4-5. During normal operation <2 mA of current flows through Q30, R94 and Q32. If a large voltage is applied to the ohms terminals, the current through this circuit will try to exceed 2 mA. This current will cause a large enough voltage drop across R94 to turn on Q31. When Q31 is on, it removes the base drive from Q30, which turns off, disconnecting the LO terminal from the ohms converter. Since Q30 is a high voltage transistor, large voltages are not applied to the ohms converter.

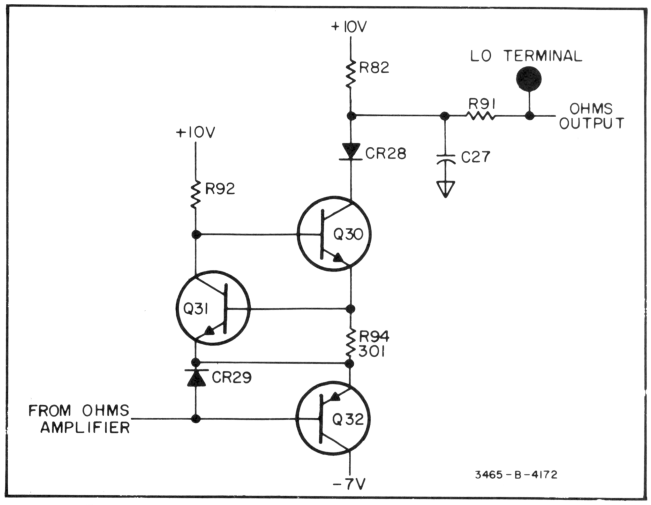


Figure 4-5. Over-Voltage Protection Circuit.

4-47. In the event of open loop ($R_x = \infty$), the ohms amplifier output begins to drive negative. The input (negative port), which is the auto-zero output, could exceed ± 1 mV under an open loop condition due to the lack of negative feedback through an R_x. This auto-zero output must be maintained at $\leq \pm$ 1 mV for accurate operation of the A-D converter. To satisfy this requirement, an overload protection circuit consisting of CR23, CR24 and R86 is used. When the ohms amplifier output goes below approximately + 1.5 V, the zener diode (CR23) turns off. The overload loop, CR24 and R86, is introduced by the turn-on of CR24 when CR23 is off. This loop provides the negative feedback required to maintain an auto-zero output $< \pm$ 1 mV. When an R_x is introduced, CR23 turns-on, CR24 turns-off, and the overload loop is inoperative.

4-48. A maximum output by the ohms converter of $\leq$ 5 V is guaranteed by a voltage divider composed of R93 and R95. Additional protection components of the ohms converter are: A) CR29 which prevents Q32 junction breakdown due to fast transients, B) CR28 which blocks negative transients that could come in via the LO terminal and C) R91 and C27 which prevent high voltage and high frequency transients.

4-49. Degradation of accuracy in the ohms function due to changes in the ohms reference with respect to the A–D reference is minimized since both reference voltages are derived from the same + 10 V reference supply. If the reference supply voltage changes, both the ohms reference and the A–D reference are affected alike and any change is effectively cancelled.

4-50. AC–to–DC Converter.

4-51. The AC–to–DC converter is an average responding ac converter. It has a bandwidth of 40 Hz to 20 kHz. The converter is composed of two stages (see Figure 7-2). The first stage, U19, is an impedance converter. The purpose of this amplifier is to provide a high impedance to the input so loading of the input signal does not occur. It also provides high drive capability for the ac converter stage, U18. The input of the impedance converter is protected against large voltage swings by diodes CR35 and CR37. Voltages in excess of + 10 V or - 7 V peak ac will turn these diodes, returning excess current to the power supply.

4-52. The impedance converter, U19, has a selection of three gains; the 100 mV, .1 mA, 100 Ω and 10 V, 10 mA, 10 kΩ ranges select a gain of 10. The ACI function selects a gain of 9.964, while the remainder of the ranges and functions select a gain of unity (see U19 Gain Table, Figure 7-2).

4-53. The second stage of the AC–to–DC converter is the ac converter, U18. A basic diagram of this stage is shown in Figure 4-6. The amplifier has three feedback loops. These loops are the ac negative feedback loop, the dc negative feedback loop, and the positive feedback loop. The ac negative feedback loop is divided into two branches; one branch for the positive cycle and the second branch for the negative cycle. Diodes CR33 and CR34 switch between the positive and negative half-cycles to introduce the correct loop for its respective half-cycle.

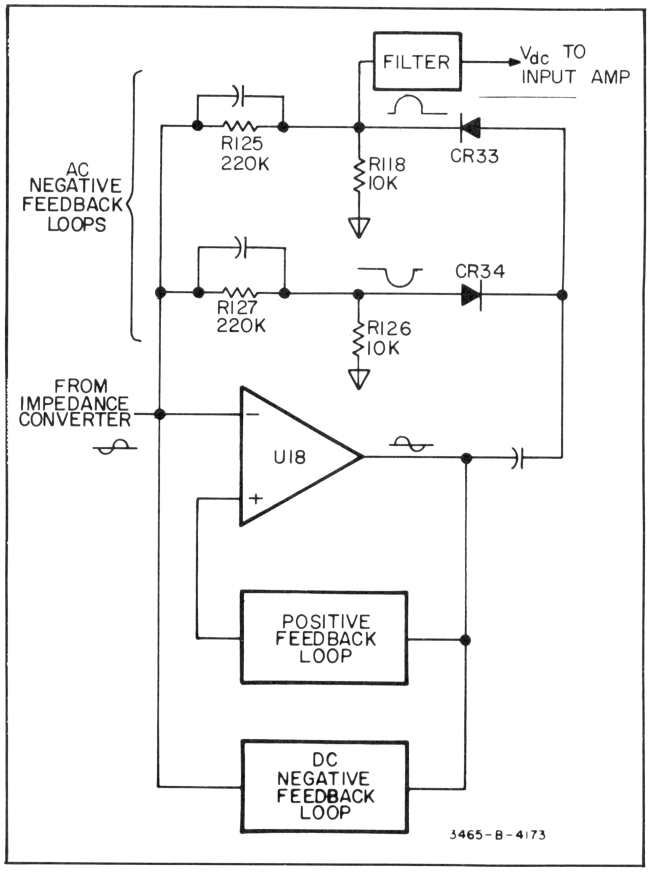


Figure 4-6. Basic Diagram, AC Converter Amplifier.

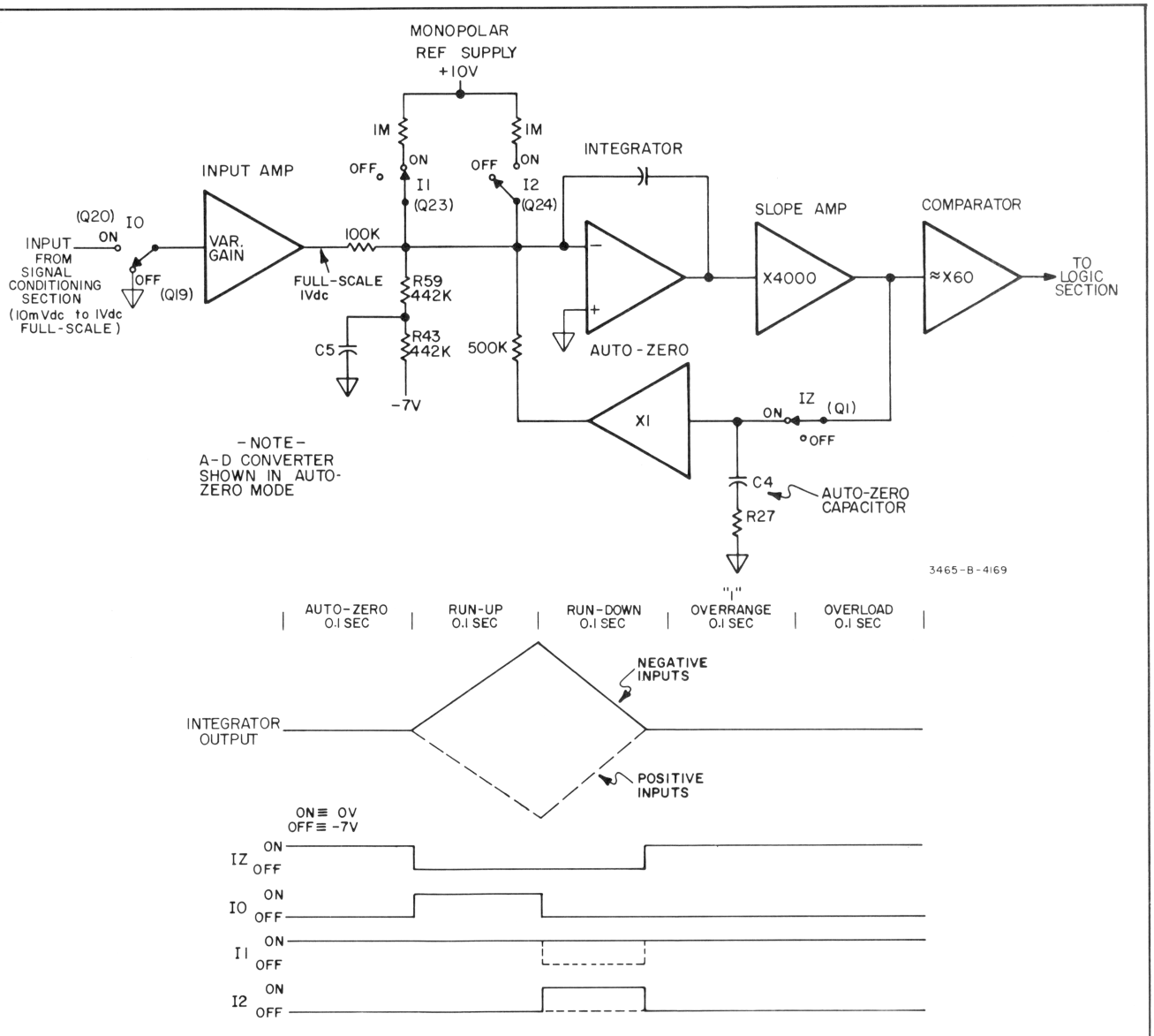
4-54. During switching of the diodes, little negative feedback is present. During the switching transition, the positive feedback loop (C45, R120 and R123) boosts the amplifier gain. This boost in gain speeds the switching transition of the diodes which gives a good frequency response at low signal levels. Once the switching transition has occurred, negative feedback is again present. The negative feedback overrides the effects of the positive feedback loop at all times other than the diode switching transition period.

4-55. The output of the AC–to–DC converter is derived from the positive half-cycle, negative feedback loop. The positive half-cycle developed across the load resistor R118 is the half-wave rectified signal of the ac converter amplifier output. This rectified signal is filtered to provide the dc output that is applied to the input amplifier during the run-up interval of the measurement sequence. For full-scale inputs, the AC–to–DC converter output is 0.8 V dc. This output is kept relatively free of the dc offset present on the negative port of U18 (pin 2) by the voltage divider R125 and R118. The portion of the offset appearing across the load resistor R118 is attenuated by a factor of 23.

4-56. A–D Conversion Using a Monopolar Reference.

4-57. Before preceeding with this discussion, review the

A–D converter description of the integrator, slope amplifier and auto-zero circuit in the simplified theory. Figure 4-7, Functional Diagram, A–D Converter, illustrates these circuits in relation to the monopolar reference supply, the input amplifier and the comparator. It also illustrates the integrator output and the four control state signals, IZ, IO, I1 and I2, with respect to the measurement sequence intervals.



MEASUREMENT INTERVAL	INPUT SIGNAL POLARITY	STATE OF CURRENT SWITCH	
		I1	I2
AUTO-ZERO	+	CLOSED	OPEN
	-	CLOSED	OPEN
RUN-UP	+	CLOSED	OPEN
	-	CLOSED	OPEN
RUN-DOWN	+	OPEN	OPEN
	-	CLOSED	CLOSED

Figure 4-7. Functional Diagram, A–D Converter.

4-58. The A–D converter of Figure 4-7 is shown in the auto-zero mode. The input amplifier is grounded at the input, control state switch I1 is closed, I2 is open and the auto-zero loop is closed. Note that the auto-zero loop does not include the input amplifier but is connected to the integrator summing junction (integrator inverting input). Also connected to the summing junction are the input amplifier output, two current paths from the monopolar reference supply and the - 7 V supply through R59 and R43.

4-59. The auto-zero loop uses a current balancing technique at the integrator summing junction to establish the reference. The basic principle is that the algebraic sum of currents at the integrator summing junction must be equal to zero. When the sum is zero, the output of the integrator will not change. If the sum is not zero, the integrator will ramp up for a negative current or ramp down for a positive current because of the inverting input.

4-60. When the auto-zero loop is closed, the currents summed at the integrator summing junction come from four sources; 1) the output of the input amplifier with its input grounded, 2) one current path of the monopolar reference supply (switch I1 closed), 3) the - 7 V supply through R43 and R59 and 4) the auto-zero loop. The input amplifier output is the analog offset of this amplifier. The current due to the - 7 V supply is roughly the negative of the current from the monopolar reference supply. The auto-zero loop then stores a voltage on the auto-zero capacitor that produces a current through R28 and R42 of the correct magnitude to force the summation of currents at the integrator summing junction to zero. Forcing the summation of currents to zero compensates for the analog offset of the input amplifier and integrator.

4-61. During the run-up interval, the auto-zero loop is opened by control state switch IZ. The voltage stored on the auto-zero capacitor is still applied to the integrator summing junction and the summation of currents remains zero. At the time the auto-zero loop is opened, the output of the signal conditioning section is switched to the input amplifier by control state signal IO. The output of the input amplifier causes the algebraic summation of currents at the integrator summing junction to deviate from zero. This causes the integrator to run-up.

4-62. At the end of the run-up interval, the input amplifier is switched back to ground by control state signal IO. The summation of currents at the integrator summing junction is again zero and if no other action were taken, the integrator output would not change. The integrator output is positive at the end of run-up for negative inputs and negative for positive inputs. At the end of the run-up interval, the polarity of the integrator output is determined by the logic section. This also identifies the polarity of the input signal.

4-63. At the beginning of the run-down interval, the logic section selects the appropriate reference to return the integrator output to zero. Run-down uses the summation of currents principle at the summing junction of the integrator. The two current paths (I1 and I2) of the monopolar reference supply provide the means of changing the summation of the currents. The summation of currents at the summing junction can be made negative by opening switch I1 and removing this current flow to the junction. The summation can be made positive by closing switch I2 in addition to I1, and providing twice the current from the monopolar reference supply. Opening switch I1 with I2 open, runs the integrator up which is required for positive inputs (see Figure 4-7). Closing I1 and I2 runs the integrator down which is required for negative inputs. The time required for the integrator to reach zero-detect during the run-down interval is proportional to the input voltage which caused run-up and determines the display.

4-64. Data Accumulator.

4-65. Refer to Figure 4-8, Data Accumulator Diagram, for this discussion. The data accumulator processes the logic signals from the logic section and provides the BCD output and the scan signals that determine the dsiplay. The data accumulator consists of a counter, data latches, a multiplexer, digit select decoder and output buffers. At the beginning of the measurement, the reset signal ($\overline{\text{RESET}}$) goes to a logic 0 to initialize the counter and digit select decoder. At the beginning of the run-down interval of the measurement sequence, the counter begins to accumulate a count proportional to the run-down time.

4-66. The counter consists of four divide by 10 circuits. The output of each circuit is a BCD number representing one digit of the input signal. At the end of the run-down interval, the transfer signal ($\overline{\text{TXFR}}$) is set to a logic 0. This stores the counter outputs in the data latches.

4-67. The scan signal will gate each BCD signal from the latches, beginning with the most significant digit first, through the multiplexer to the output. At the same time that the scan gates the digits through the multiplexer, the gating signal is output to the display as a digit activation pulse.

4-68. The BCD output of the multiplexer is applied to the display section (see Figure 7-4). The $\overline{\text{BCD}}$ is applied to quad NAND gates in the display section where the $\overline{\text{BCD}}$ logic is converted to BCD logic. The BCD is applied to the seven segment decoder where it is transformed to a seven bit binary number and applied to each numeral in the display. As the digit activation pulse from the data accumulator sequentially activates each numeral from most significant to least significant, the seven bit binary data will be displayed.

4-69. Display.

4-70. Refer to Figure 7-4 for this discussion. The display segments are powered by a + 3 V supply. This voltage is

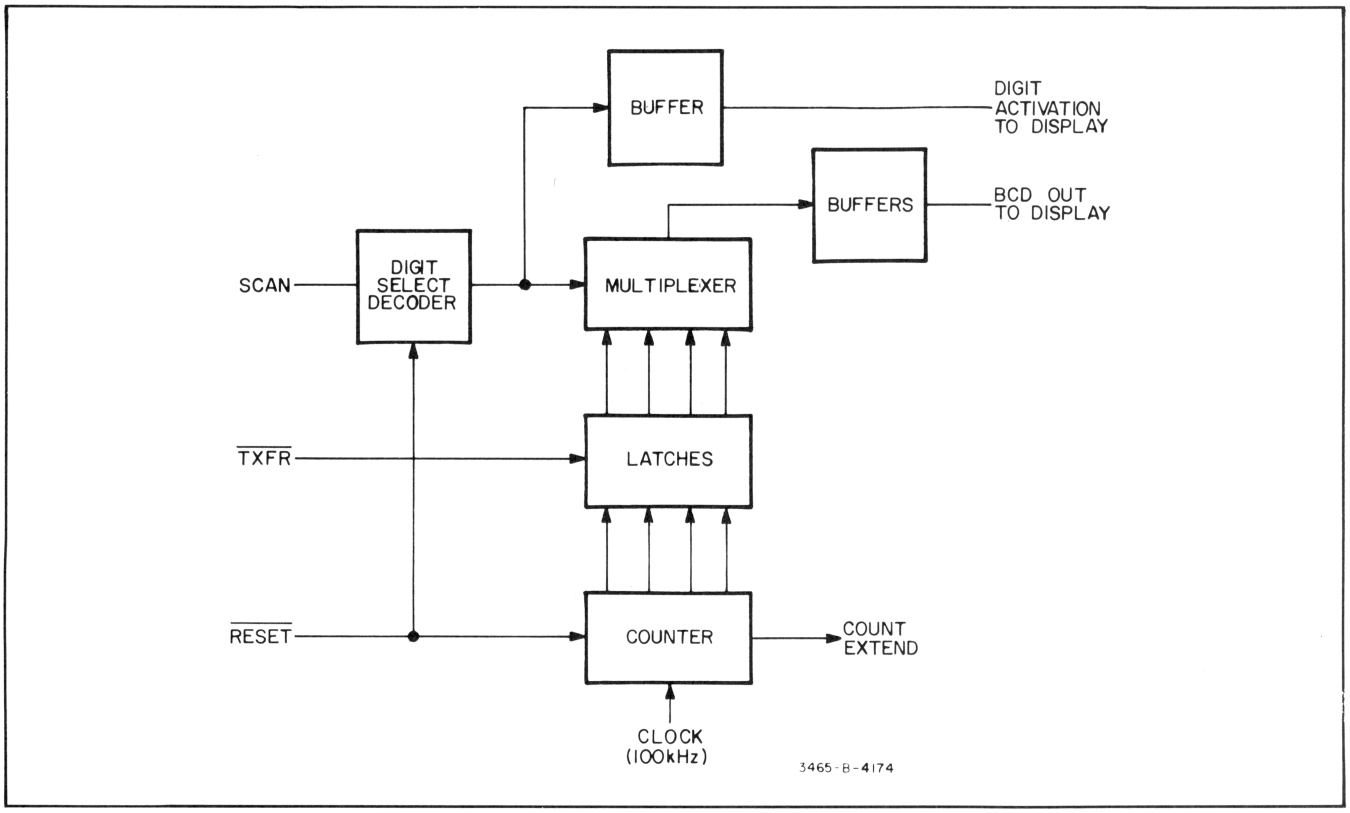


Figure 4-8. Data Accumulator.

derived from VB and the + 11 V output of the power supply. A series voltage regulator, Q21, Q22 and Q23 maintains the + 3 V output constant. This provides constant display intensity for changes in the magnitude of VB due to battery life and results in low power consumption for a high VB (new or recharged batteries).

4-71. Twenty-five connections interface the display and the main assembly. Table 4-1 indicates each terminal and the source of the signal from the main assembly.

Table 4-1. Display Interface Connections.

CONNECTION DESIGNATION	SOURCE OF SIGNAL	
DIGIT STROBES: MSD, 2MSD, 3MSD, LSD BCD: 1, 2, 4, 8	DATA ACCUMULATOR (A1U11)	
DECIMAL POINT: A, B, C, D	RANGE SWITCHES	
$\overline{\text{POLARITY ENABLE}}$: $\overline{\text{PE}}$	FUNCTION SWITCHES	
POLARITY: PL SAMPLE RATE: SR	A1U4	LOGIC SECTION
OVERRANGE: OR OVERLOAD: OL	A1U5	
$\overline{\text{TRANSFER}}$: $\overline{\text{TR}}$	A1U6	
+ VB, + 11 V, GND, - 7 V, - 7 V_F and - 12 V.	POWER SUPPLY	
PIN 25	NO CONNECTION	

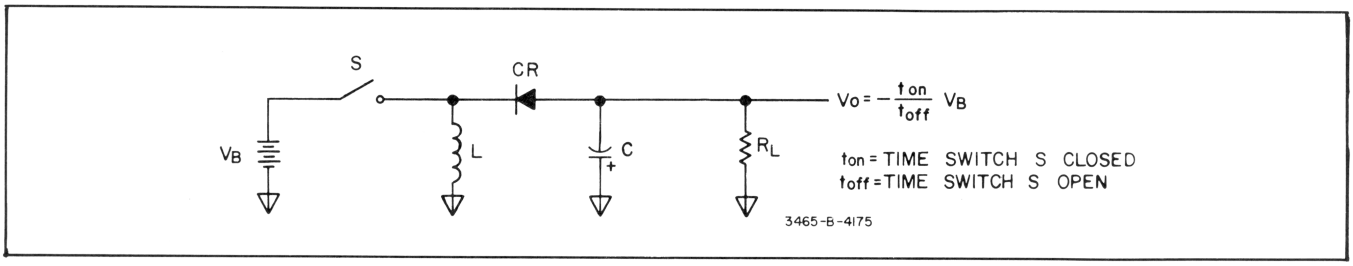


Figure 4-9. Basic Diagram, DC—to—DC Converter.

4-72. Power Supply.

4-73. This paragraph is a description of a simple dc-to-dc converter. Figure 4-9 is a diagram of this converter. When switch S is closed (t_{on}), battery voltage VB is applied to the inductor L. Since the battery voltage is constant, the inductor current increases linearly with time. The inductor current establishes a magnetic field which stores energy transferred from the battery. During t_{on}, C supplies current to the load, R_L. When switch S is opened (t_{off}), the voltage across the inductor inverts and forward biases diode CR. For a constant V_o, the inductor current decreases linearly with time and transfers energy to the capacitor and load resistor, C and R_L. The energy transferred from the battery to the load is controlled by switch S. By controlling switch S the output voltage can be made greater than, equal to or less than the battery voltage VB and can be regulated for changes in the battery voltage (VB) and in the load (R_L). For a steady state condition, the duty-cycle of switch S is

$$\frac{t_{on}}{T} = \frac{|V_o|}{|V_o| + VB}$$

t_{on} = time switch S closed.
T = period of one cycle.

The duty-cycle depends only on the output voltage (V_o) and the battery voltage (VB).

4-74. A simplified diagram of the dc-to-dc converter is shown in Figure 4-10. Refer to this diagram and the converter of Figure 7-5 for this discussion. A negative output is derived from a portion of the energy stored in the primary winding inductance or magnetizing inductance of T1 while the switch, Q33 is on. This output is obtained by the same process described previously for the simple switch-type dc—to—dc converter. A positive output is developed by transformer-coupling a portion of the energy stored in the primary winding inductance through the secondary winding of T1. This output is equal to the turns-ratio times the voltage developed by the primary of T1 across C34 when switch Q33 is off.

4-75. The following paragraphs describe the circuit operation of the dc—to—dc converter. When the battery voltage VB is applied to the circuit, Q33 saturates. A constant voltage is applied across the primary of T1. The collector current determined by the constant battery voltage (VB) and the primary winding inductance, increases linearly with time until Q33 comes out of saturation ($h_{FE}I$). As this occurs, the collector of Q33 begins a negative transition. This transition at pin 1 of transformer T1 causes pin 3 of T1 to begin a positive transition. The positive transition is applied to the base of Q33 by the feedback circuit R81 and C25 and turns Q33 off. As Q33 turns off, the voltage across

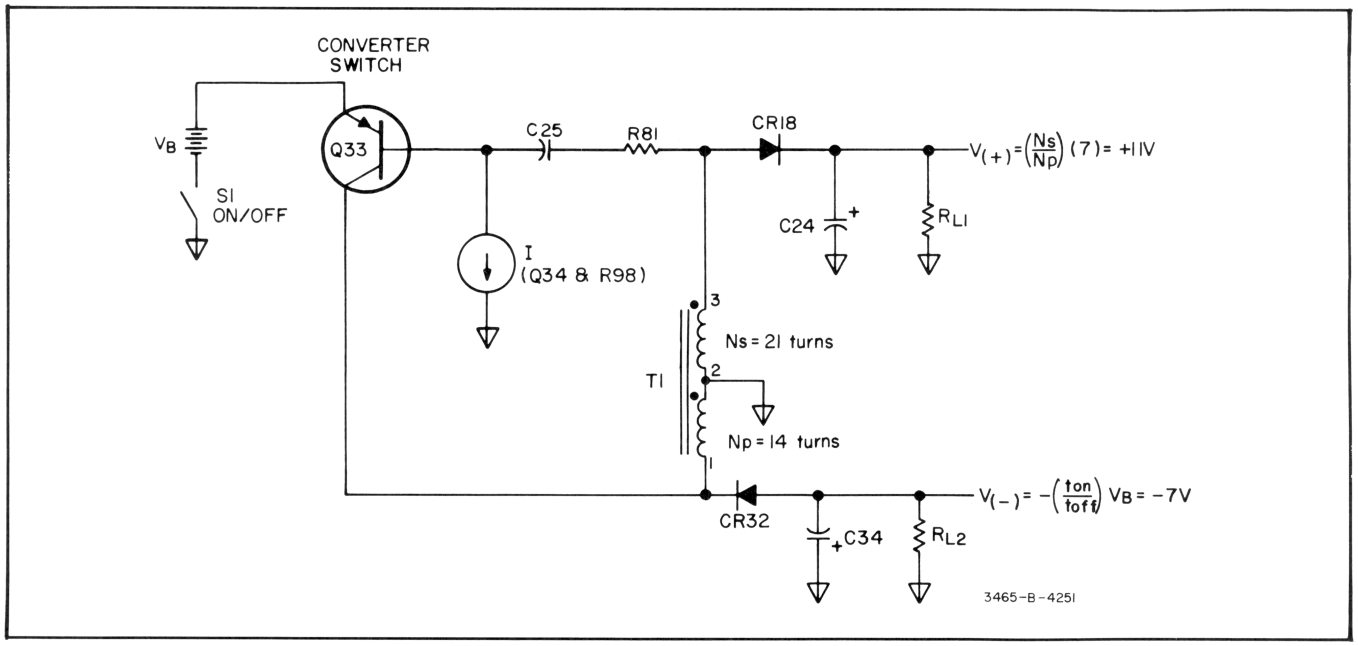


Figure 4-10. Simplified Diagram, DC—to—DC Converter.

the primary and secondary windings of T1 inverts and forward biases CR18 and CR32. The energy stored in the primary winding inductance of T1 is transferred to the output capacitors, C24 and C34, and their loads.

4-76. The cycle ends as Q33 turns on. This results when either the voltage at the base of Q33 decreases to the point that Q33 begins to turn on or the energy stored in transformer T1 goes to zero. Both events cause the collector of Q33 to begin a positive transition. Pin 3 of transformer T1 begins a negative transition at the same time and is applied to the base of Q33 through the feedback circuit of R81 and C25. This action causes Q33 to saturate and the cycle begins again.

4-77. Converter Regulation. Regulation of the dc–to–dc converter is accomplished by controlling the energy transfer to the load. The energy transfer to the load is controlled by the switch, Q33 and the current source I. The magnitude of I is determined by Q34, R98 and the voltage at the base of Q34. The base of Q34 is driven by U17. The inverting input of U17 is connected to ground through R116. A 10–to–7 voltage divider (R117 and R114) is connected to the non-inverting input of U17. One end of the divider (R117) senses the constant voltage of the + 10 V series voltage regulator. The other end of the divider (R114) senses the - 7 V output of the dc–to–dc converter. A change in voltage at the - 7 V output results in an error voltage at the non-inverting input of U17 and is amplified by U17. The output voltage of U17 drives the base of Q34 and regulation of the - 7 V output is achieved. Since the + 11 V output is the transformer turns-ratio times the - 7 V output, this output is also regulated.

4-78. + 10 V Series Voltage Regulation.

4-79. The temperature compensated zener diode CR17 is the voltage reference from which the + 10 V reference is derived. The zener voltage is applied to the non-inverting input of U16. A resistor divider in the precision resistor pack (R75) senses the voltage at the output. A portion of the voltage is fed to the inverting input of U16. This error voltage is amplified by U16 to drive Q26. The collector current of Q26 then provides base drive for the series pass transistor Q27. To ensure turn-on of the dc–to–dc converter, the collector, as opposed to the emitter of the series pass transistor Q27, is connected to the output. The low collector–to–emitter saturation voltage aids in the turn-on process of the converter. This ensures start-up for battery voltages as low as 2 to 3 volts. One advantage to this configuration is that the + 11 V supply can decrease to within the collector–to–emitter saturation voltage of the + 10 V regulated output and regulation is still maintained.

4-80. - 12 V Supply.

4-81. Refer to Figure 7-5. The - 12 V output is developed from the - 7 V supply by use of a voltage doubler circuit driven by the 100 kHz clock generated in the logic section. Transistors Q21 and Q22 prevent loading of the clock.

4-82. Battery Low-Voltage Detection.

4-83. Refer to the power supply schematic, Figure 7-5. The battery low-voltage detection circuit is comprised of a differential amplifier, Q36 and Q37. The voltage at the base of Q36 is set at about + 2.9 V by the voltage divider R139 and R141. If the battery voltage (+VB) is greater than + 2.9 V, Q36 conducts and Q37 is off. When the battery voltage drops below + 2.9 V, Q37 turns on providing base drive for Q38. When Q38 is on, the base of Q34 is pulled to - 7 V and Q34 turns off. This action turns the ac-to-dc converter of the power supply off removing all power supply outputs. This removes the front panel display indication. To reinstate the display, the OFF/ON switch must be turned OFF and again ON. The display indication will reappear while capacitor C51 charges to + 2.9 V. When the voltage on C51 (which is the base voltage of Q36) exceeds the battery voltage (+ VB), the circuit deactivates the power supply as previously described and the display indication disappears again.

WARNING

These servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

Table 5-1. Test Equipment Required.

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	RECOMMENDED MODEL
Digital Volt/Ohmmeter	DC Volts: 1 V, 10 V and 100 V range Accuracy: ± 0.04% Input Resistance: 10 MΩ Ohms: 200 kΩ Accuracy: ± 0.07%	-hp- 3470 System; -hp- 34702A Multimeter
Digital Voltmeter	DC Volts: 5 digit resolution to 1 μV on 100 mV dc range. Accuracy: ± 0.007% AC Volts: 1 V and 10 V range Frequency: 40 Hz to 20 kHz Accuracy: 0.25%	-hp- 3450B
AC Calibrator/ High Voltage Amplifier	Frequency: 20 Hz to 100 kHz Output: 1 mV to 1000 V Accuracy (mid band): ± 0.1%	-hp- 745A/746A
DC Standard	Output: 1 mV to 1000 V Accuracy: ± 0.02%	-hp- 740B
Meter Calibrator	Output: 1 A Accuracy: ± 0.1%	-hp- 6920B
Electronic Counter	Frequency: 50 and 60 Hz Accuracy: ± 0.01%	-hp- 5300A/5302A
Power Supply	Output: 20 V, 1 A	-hp- 6294A
Resistor Decade Box	10 Ω, 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ and 1 MΩ steps Accuracy: ± 0.005%	General Radio Mdl GR 1433-Z
Capacitor	1 μF ± 10%	0160-3407
Resistors	1 Ω ± 0.1% 10 Ω ± 0.1% 1 kΩ ± 0.1% 2 kΩ ± 0.1% 10 kΩ ± 0.1% 20 kΩ ± 0.1% 100 kΩ ± 0.1% 1 MΩ ± 0.1% 10 MΩ ± 0.1% 30 Ω ± 1% 100 Ω ± 1% 1 kΩ ± 1% 22 kΩ ± 1% 66.5 kΩ ± 1% 1 MΩ ± 1%	0811-0615 0698-5452 0698-3491 0698-6612 0698-4157 0698-6943 0698-4158 0698-6369 0698-8194 0757-0388 0698-7320 0727-0751 0757-1087 0698-4503 0698-5049

SECTION V
MAINTENANCE

5-1. INTRODUCTION.

5-2. This section of the manual contains Performance Tests and Adjustment Procedures. The Performance Tests are designed to verify the critical specifications listed in Table 1-1. A Performance Test Card is at the end of this section for recording the results of the performance tests.

5-3. Test Equipment Required.

5-4. Equipment required for the performance tests and adjustment procedures is listed in Table 5-1, Recommended Test Equipment. Equipment that satisfies the critical specifications given in the table may be substituted for a recommended model.

NOTE

Throughout the Performance Tests and Adjustment Procedures, the -hp- Model 3465A is referred to as Multimeter.

5-5. PERFORMANCE TESTS.

5-6. DC Voltmeter Accuracy Test.

5-7. A DC Standard is required for this test.

a. Set the Multimeter function to DCV (⎓ V) and range to 10 m. Short the VΩ and COM terminals together and adjust the display for 0.000, using the ZERO ADJ on the rear panel.

b. Disconnect the short and connect the DC Standard between the VΩ and COM terminals.

c. Check all the dc ranges listed in Table 5-2 for the tolerances indicated.

CAUTION

Do not apply more than 1000 V, otherwise damage to the instrument may result.

Table 5-2. DC Voltmeter Accuracy Test.

DC Range	DC Standard Output	Multimeter Display Limits
10 mV	± 0.00100 V ± 0.00500 V ± 0.01000 V	.998 – 1.002 mV 4.996 – 5.004 mV 9.995 – 10.005 mV
100 mV	± 0.01000 V ± 0.05000 V ± 0.10000 V	9.99 – 10.01 mV 49.98 – 50.02 mV 99.97 – 100.03 mV
1 V	± 0.10000 V ± 0.50000 V ± 1.00000 V	.0999 – .1001 V .4998 – .5002 V .9997 – 1.0003 V
10 V	± 1.00000 V ± 5.00000 V ± 10.0000 V	.999 – 1.001 V 4.998 – 5.002 V 9.997 – 10.003 V
100 V	± 10.0000 V ± 50.0000 V ± 100.000 V	9.99 – 10.01 V 49.98 – 50.02 V 99.97 – 100.03 V
1000 V	± 100.000 V ± 500.000 V ± 1000.00 V	99.8 – 100.2 V 499.7 – 500.3 V 999.6 – 1000.4 V

5-8. DC Ammeter Accuracy Test.

5-9. This test requires the use of a power supply, a DC Differential Voltmeter and a precision resistor listed in Table 5-3 (part numbers are given in Table 5-1) or a resistor decade box.

a. Connect the Multimeter and test equipment as shown in Figure 5-1.

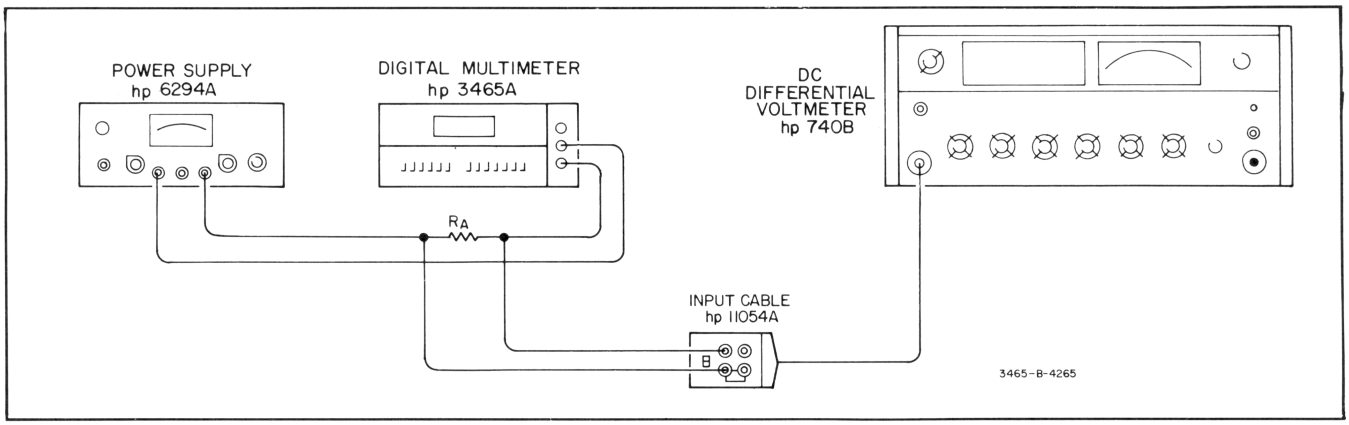


Figure 5-1. DC Ammeter Accuracy Test.

Table 5-3. DC Ammeter Accuracy Test.

Multimeter Range	Current Level	R_A	Differential VM Reading	Multimeter Display Limits
100 μA	10 μA 50 μA 100 μA	100 kΩ ± 0.1%	1.0000 V 5.0000 V 10.000 V	9.98 – 10.02 μA 49.95 – 50.05 μA 99.92 – 100.08 μA
1 mA	.1 mA .5 mA 1 mA	1 kΩ ± 0.1%	.10000 V .50000 V 1.0000 V	.0998 – .1002 mA .4995 – .5005 mA .9992 – 1.0008 mA
10 mA	1 mA 5 mA 10 mA	1 kΩ ± 0.1%	1.0000 V 5.0000 V 10.000 V	.998 – 1.002 mA 4.993 – 5.007 mA 9.988 – 10.012 mA
100 mA	10 mA 50 mA 100 mA	10 Ω 0.1%	.10000 V .5000 V 1.0000 V	9.93 – 10.07 mA 49.69 – 50.31 mA 99.39 – 100.61 mA
1000 mA	100 mA 500 mA 1000 mA	1 Ω 0.1%	.10000 V .50000 V 1.0000 V	99.3 – 100.7 mA 496.9 – 503.1 mA 993.9 – 1006.1 mA

b. Connect the 100 kilohm ± 0.1% resistor in the R_A position as shown.

c. Set the Multimeter function to DCA (⎓ A) and range to 100 μA. Adjust the power supply output for a differential voltmeter reading of 1.000 V. The Multimeter should indicate 99.98 to 100.02 μA.

d. Check all the Multimeter ranges, using the values of R_A and differential voltmeter readings shown in Table 5-3. The Multimeter display should indicate within the limits provided.

5-10. Ohms Accuracy Test.

5-11. A precision resistive decade box will be required for this test. It should be calibrated and have a known accuracy of .005%.

a. Connect the equipment as shown in Figure 5-2.

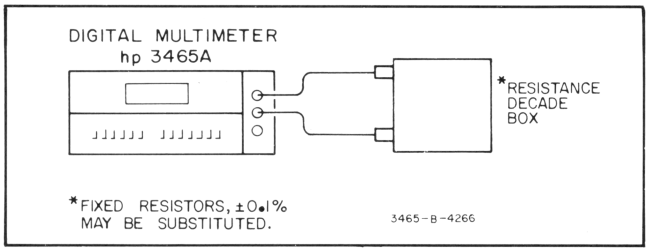


Figure 5-2. Ohms Accuracy Test.

b. Set the Multimeter function to OHMS (Ω) and check all the ranges in Table 5-4 using the decade box to supply the indicated resistances. The Multimeter display should indicate within the limits provided.

5-12. AC Voltage Accuracy Test.

5-13. An AC Calibrator and High Voltage Amplifier will be required for the following tests.

Table 5-4. Ohms Accuracy Test.

Multimeter Range	Resistive Decade Setting	Multimeter Display Limits
100 Ω	10 Ω 50 Ω 100 Ω	9.98 – 10.02 Ω 49.97 – 50.03 Ω 99.96 – 100.04 Ω
1 kΩ	100 Ω 500 Ω 1 kΩ	.0999 – .1001 kΩ .4998 – .5002 kΩ .9997 – 1.0003 kΩ
10 kΩ	1 kΩ 5 kΩ 10 kΩ	.999 – 1.001 kΩ 4.998 – 5.002 kΩ 9.997 – 10.003 kΩ
100 kΩ	10 kΩ 50 kΩ 100 kΩ	9.99 – 10.01 kΩ 49.98 – 50.02 kΩ 99.97 – 100.03 kΩ
1000 kΩ	100 kΩ 500 kΩ 1000 kΩ	99.9 – 100.1 kΩ 499.8 – 500.2 kΩ 999.7 – 1000.3 kΩ
10 M	1 MΩ 5 MΩ 10 MΩ	.998 – 1.002 MΩ 4.994 – 5.006 MΩ 9.989 – 10.011 MΩ

a. Set the Multimeter function to ACV (~V). Connect the AC Calibrator between the VΩ terminal and COM terminal. Be sure to connect the Calibrator sense leads.

b. Check the voltage ranges listed in Table 5-5 at each frequency listed. The Multimeter should indicate within the limits provided.

5-14. AC Ammeter Accuracy Test.

5-15. An AC Calibrator, a 3450B Digital Voltmeter and discrete resistors (R_A) indicated in Table 5-6 are required for this test.

a. Set the Multimeter function to ACA (~ A) and range to 100 μA. Connect the equipment as shown in Figure 5-3 using a discrete resistor for R_A. (To select R_A, note the

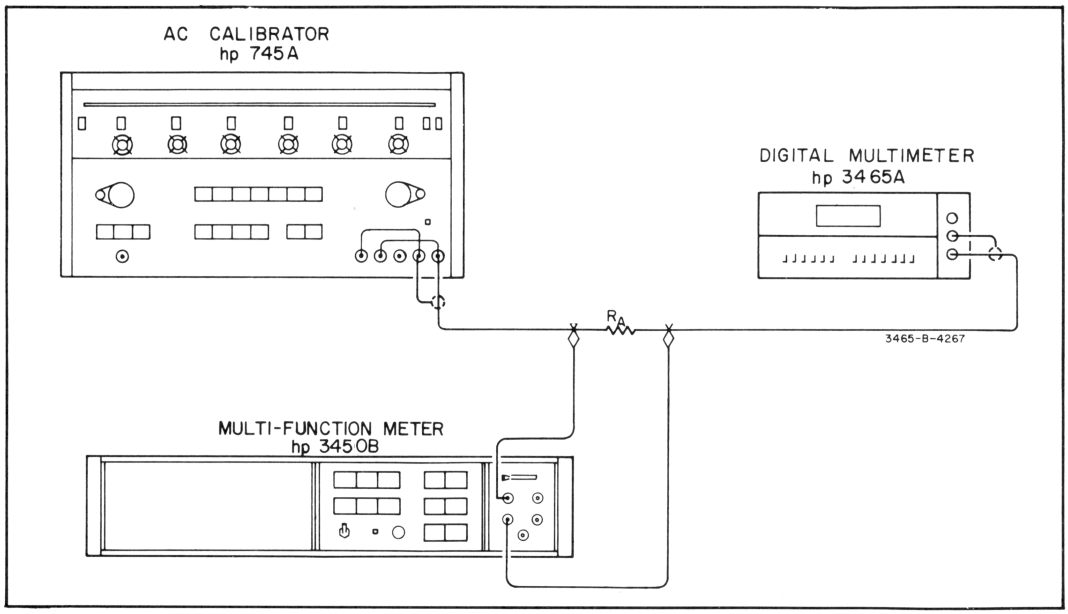


Figure 5-3. AC Ammeter Accuracy Test 100 μA thru 10 mA Range.

Table 5-5. AC Voltage Accuracy Test.

Multimeter Range	AC Standard Output	Test Frequency	Multimeter Display Limits
100 mV	10 mV	40 Hz, 400 Hz, 10 kHz	9.93 – 10.07 mV
	50 mV	40 Hz, 1 kHz, 10 kHz	49.87 – 50.13 mV
	100 mV	40 Hz, 5 kHz, 10 kHz	99.80 – 100.20 mV
	10 mV	11 kHz, 15 kHz, 20 kHz	9.80 – 10.20 mV
	50 mV	11 kHz, 15 kHz, 20 kHz	49.60 – 50.40 mV
	100 mV	11 kHz, 15 kHz, 20 kHz	99.35 – 100.65 mV
1 V	100 mV	40 Hz, 400 Hz, 10 kHz	.0993 – .1007 V
	500 mV	40 Hz, 1 kHz, 10 kHz	.4987 – .5013 V
	1 V	40 Hz, 5 kHz, 10 kHz	.9980 – 1.0020 V
	100 mV	11 kHz, 15 kHz, 20 kHz	.0980 – .1020 V
	500 mV	11 kHz, 15 kHz, 20 kHz	.4960 – .5040 V
	1 V	11 kHz, 15 kHz, 20 kHz	.9960 – 1.0065 V
10 V	1 V	40 Hz, 400 Hz, 10 kHz	.993 – 1.007 V
	5 V	40 Hz, 1 kHz, 10 kHz	4.987 – 5.013 V
	10 V	40 Hz, 5 kHz, 10 kHz	9.980 – 10.020 V
	1 V	11 kHz, 15 kHz, 20 kHz	.980 – 1.020 V
	5 V	11 kHz, 15 kHz, 20 kHz	4.960 – 5.040 V
	10 V	11 kHz, 15 kHz, 20 kHz	9.935 – 10.065 V
100 V	10 V	40 Hz, 400 Hz, 10 kHz	9.99 – 10.07 V
	50 V	40 Hz, 1 kHz, 10 kHz	49.87 – 50.13 V
	100 V	40 Hz, 5 kHz, 10 kHz	99.80 – 100.20 V
	10 V	11 kHz, 15 kHz, 20 kHz	9.80 – 10.20 V
	50 V	11 kHz, 15 kHz, 20 kHz	49.60 – 50.40 V
	100 V	11 kHz, 15 kHz, 20 kHz	99.35 – 100.65 V
1000 V	100 V	40 Hz, 400 Hz, 1 kHz	99.3 – 100.7 V
	500 V	40 Hz, 400 Hz, 1 kHz	498.7 – 501.3 V
	100 V	1.5 kHz, 2 kHz	99.0 – 101.0 V
	500 V	1.5 kHz, 2 kHz	497.0 – 503.0 V

value of R_A as directed in Table 5-6 and install the part number indicated in Table 5-1. A resistor decade box *WILL NOT* provide the accuracy required of R_A because of the introduction of wire-wound resistor inductance by the decade box).

b. Set the AC Calibrator frequency to the desired test frequency indicated in Table 5-6.

c. Adjust the AC Calibrator amplitude for a 3450B Digital Voltmeter display as indicated in Table 5-6 for the range and current level being tested.

d. *REMOVE* the 3450B Digital Voltmeter from the test setup.

e. Verify the Multimeter Display Limits as indicated in the last column of Table 5-6.

f. Reconnect the 3450B Digital Voltmeter as shown in Figure 5-3.

g. Repeat Steps b through f for each frequency of each range and current level listed in Table 5-6. Change R_A as indicated for each current level.

h. To check the 100 mA and 1 A ranges, it is necessary to use an ac current source capable of these current outputs such as the 6920B Meter Calibrator. Set the 6920B OUTPUT SWITCH to OFF and replace the AC Calibrator with the 6920B.

i. Set the 6920B FUNCTION switch to AC and RANGE switch to 100 milliamperes. Adjust the digital potentiometer readout control to provide a 10 mA output.

j. Set the OUTPUT SWITCH to ON HOLD. Verify Multimeter Display Limits shown in Table 5-7.

k. Return the 6920B OUTPUT SWITCH to OFF before changing ranges. Adjust the 6920B for the 100 mA range outputs listed in Table 5-7 and verify the Multimeter Display Limits.

l. Change Multimeter range to 1000 mA and verify Multimeter Display Limit for the 100 mA input.

m. With the 6920B OUTPUT switch at OFF, change the 6920B range to 1A. Check the Multimeter Display Limits for the 500 mA and 1000 mA inputs indicated in Table 5-7.

Table 5-6. AC Ammeter Accuracy Test, 100 μA thru 10 mA Ranges.

Multimeter Range	3450B Digital Voltmeter Display Indication	AC Calibrator Frequency	R_A Value	Current Level	Multimeter Display Limits
100 μA	.99985 to 1.00015	40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	100 kΩ ± .1%	10 μA	9.91 – 10.09 μA 9.92 – 10.08 μA 9.79 – 10.21 μA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	20 kΩ ± .1%	50 μA	49.75 – 50.25 μA 49.82 – 50.18 μA 49.55 – 50.75 μA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	10 kΩ ± .1%	100 μA	99.55 – 100.45 μA 99.70 – 100.30 μA 99.25 – 100.75 μA
1 mA	9.9985 to 10.0015	40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	100 kΩ ± .1%	.1 mA	.0991 – .1009 mA .0992 – .1008 mA .0979 – .1021 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	20 kΩ ± .1%	.5 mA	.4975 – .5025 mA .4982 – .5018 mA .4955 – .5045 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	10 kΩ ± .1%	1 mA	.9955 – 1.0045 mA .9970 – 1.0030 mA .9925 – 1.0075 mA
10 mA	9.9985 to 10.0015	40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	10 kΩ ± 0.1%	1 mA	.991 – 1.009 mA .992 – 1.008 mA .979 – 1.021 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	2 kΩ ± .1%	5 mA	4.975 – 5.025 mA 4.982 – 5.018 mA 4.955 – 5.045 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	1 kΩ ± .1%	10 mA	9.955 – 10.045 mA 9.970 – 10.030 mA 9.925 – 10.075 mA

Table 5-7. AC Ammeter Accuracy Test, 100 mA and 1000 mA Ranges.

Multimeter Range	Output Meter Calibration	Multimeter Display Limits
100 mA	10 mA	9.87 – 10.13 mA
	50 mA	49.55 – 50.45 mA
	100 mA	99.15 – 100.85 mA
1000 mA	100 mA	98.7 – 101.3 mA
	500 mA	495.5 – 504.5 mA
	1000 mA	991.5 – 1008.5 mA

5-16. AC Normal-Mode Rejection Test.

5-17. AC normal-mode rejection is the ratio of the peak normal-mode voltage to the resultant error in reading.

$$NMR_{(db)} = 20 \log_{10} \frac{\text{Peak ac superimposed voltage}}{\text{Effect on reading (peak volts)}}$$

An AC Calibrator, an Electronic Counter, a 1 μF capacitor (-hp- Part No. 0160-3407) and a 22 kΩ resistor (-hp- Part No. 0757-1087) are required for this test.

a. Connect the test equipment as shown in Figure 5-4. Do not connect the Multimeter at this time.

b. Using the Electronic Counter as a monitor, adjust the AC Calibrator frequency to 60 Hz ± 0.1%.

c. Set the Multimeter function to DCV (⎓ V) and range to 10 V. Short the Multimeter input and note the indication.

d. Disconnect the short and connect the AC Calibrator to the Multimeter input. Adjust the Calibrator output to 7.07 V rms (10 V peak).

e. The Multimeter indication should not vary more than .007 V from the indication noted in Step C. This verifies a normal-mode rejection of greater than 60 dB.

f. Repeat Steps c, d and e for an AC Calibrator output frequency of 50 Hz ± 0.1% as monitored by the Electronic Counter.

5-18. AC Effective Common-Mode Rejection Test.

5-19. An AC Calibrator, an Electronic Counter and a 1 kΩ ± 1% resistor are required for this test.

a. Connect a 1 kΩ resistor between the VΩ and COM terminals.

b. Set the Multimeter function to DCV (⎓ V) and range to 1 V. Note the Multimeter indication.

c. Connect the AC Calibrator to the Multimeter as shown in Figure 5-5.

d. Using the Electronic Counter as a monitor, set the AC Calibrator frequency to 60 Hz ± 0.1% (50 Hz ± 0.1% if operating Multimeter from a 50 Hz source).

e. Adjust the Calibrator output to 7.07 V rms (10 V peak).

f. Note the Multimeter indication. The reading should not vary more than .00001 V from reading noted in Step b verifying an ac common-mode rejection of greater than 120 dB.

5-20. DC Voltmeter Input Resistance Test.

5-21. A DC Standard and a 10 MΩ ± 0.1% resistor (-hp- Part No. 0698-8194) are required for this test.

a. Connect the Multimeter, DC Standard and resistor as shown in Figure 5-6.

b. Set the Multimeter function to DCV (⎓ V) and range to 10 V.

c. Connect a jumper across the 10 MΩ resistor and adjust the DC Standard to provide a Multimeter display of +10.000.

d. Remove the jumper from the 10 MΩ resistor. The Multimeter display should indicate 4.950 to 5.027 verifying an input resistance of 10 MΩ ± 1% on the 10 V through 1000 V ranges.

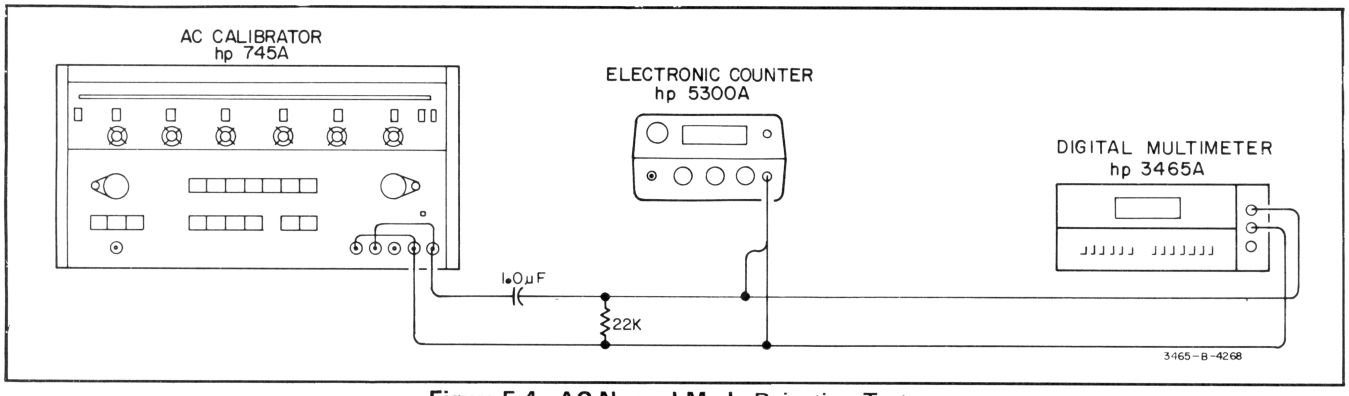


Figure 5-4. AC Normal-Mode Rejection Test.

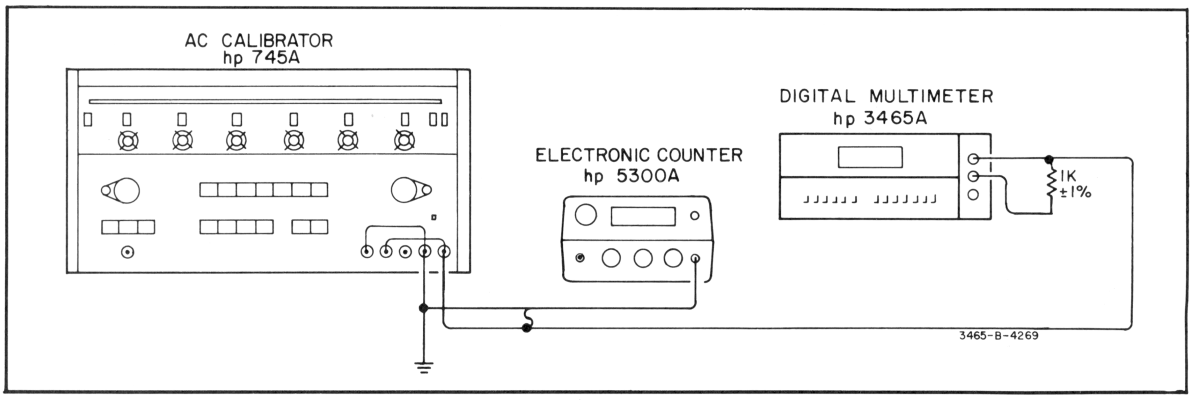


Figure 5-5. AC Effective Common-Mode Rejection Test.

e. Change the DC Standard output to 0 V and change the Multimeter range to 1 V.

f. Connect a jumper across the 10 MΩ resistor and adjust the DC Standard to provide a Multimeter display of +1.0000.

g. Remove the jumper from the 10 MΩ resistor. The Multimeter display should indicate .9990 or greater verifying an input resistance of $\geq 10^{10}$ on the 10 mV through 1 V ranges.

5-22. AC Voltmeter Input Impedance Test.

5-23. An AC Calibrator and a 1 MΩ ± 0.1% resistor (-hp-Part No. 0698-6369) are reqired for this test.

a. Connect the AC Calibrator and a 1 MΩ resistor as shown in Figure 5-7. Connect a jumper across the resistor.

b. Set the Multimeter function to ACV (~ V) and range to 1 V.

c. Set the AC Calibrator frequency to 40 Hz and adjust the output amplitude for a Multimeter display of 1.0000.

d. Remove the jumper from the 1 MΩ resistor. The Multimeter display should indicate .4950 to .5027 verifying an input impedance resistive component of 1 MΩ ± 1%.

e. Maintain the AC Calibrator at 40 Hz and adjust the output amplitude for a Multimeter display of 1.0000.

f. Change the AC Calibrator frequency to 3183 Hz. The Multimeter display should indicate .7071 to 1.0000 verifying a shunt capacitance less than 100 pF.

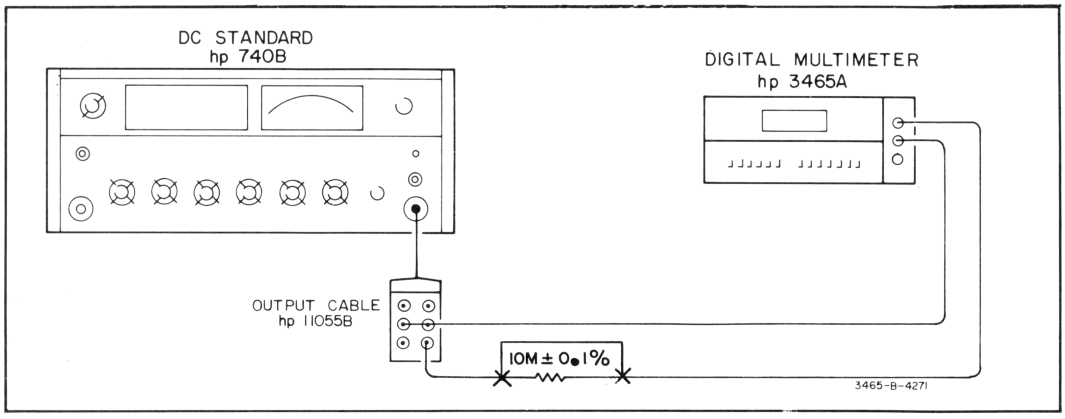


Figure 5-6. DC Voltmeter Input Resistance Test.

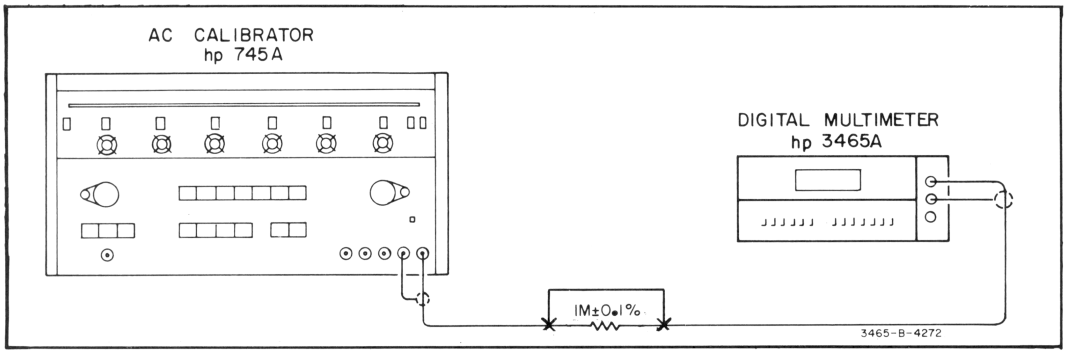


Figure 5-7. AC Voltmeter Input Impedance Test.

ADJUSTMENT PROCEDURES

5-24. ADJUSTMENT PROCEDURES.

WARNING

Adjustment Procedures of Section V are intended for qualified service personnel only. To reduce the possibility of electrical shock, only qualified personnel are to perform maintenance duties.

5-25. The following procedures should be performed only after it has been determined from Performance Tests that the Multimeter does not meet specifications. If any adjustment in these procedures cannot be made, refer to the troubleshooting procedures of Section VII. Location of the Multimeter adjustments is shown in Figure 5-8.

NOTE

After use of a soldering iron, flux remover or freon on the A1 Assembly, allow 10 to 15 minutes for the instrument to thermally stabalize before an adjustment is performed.

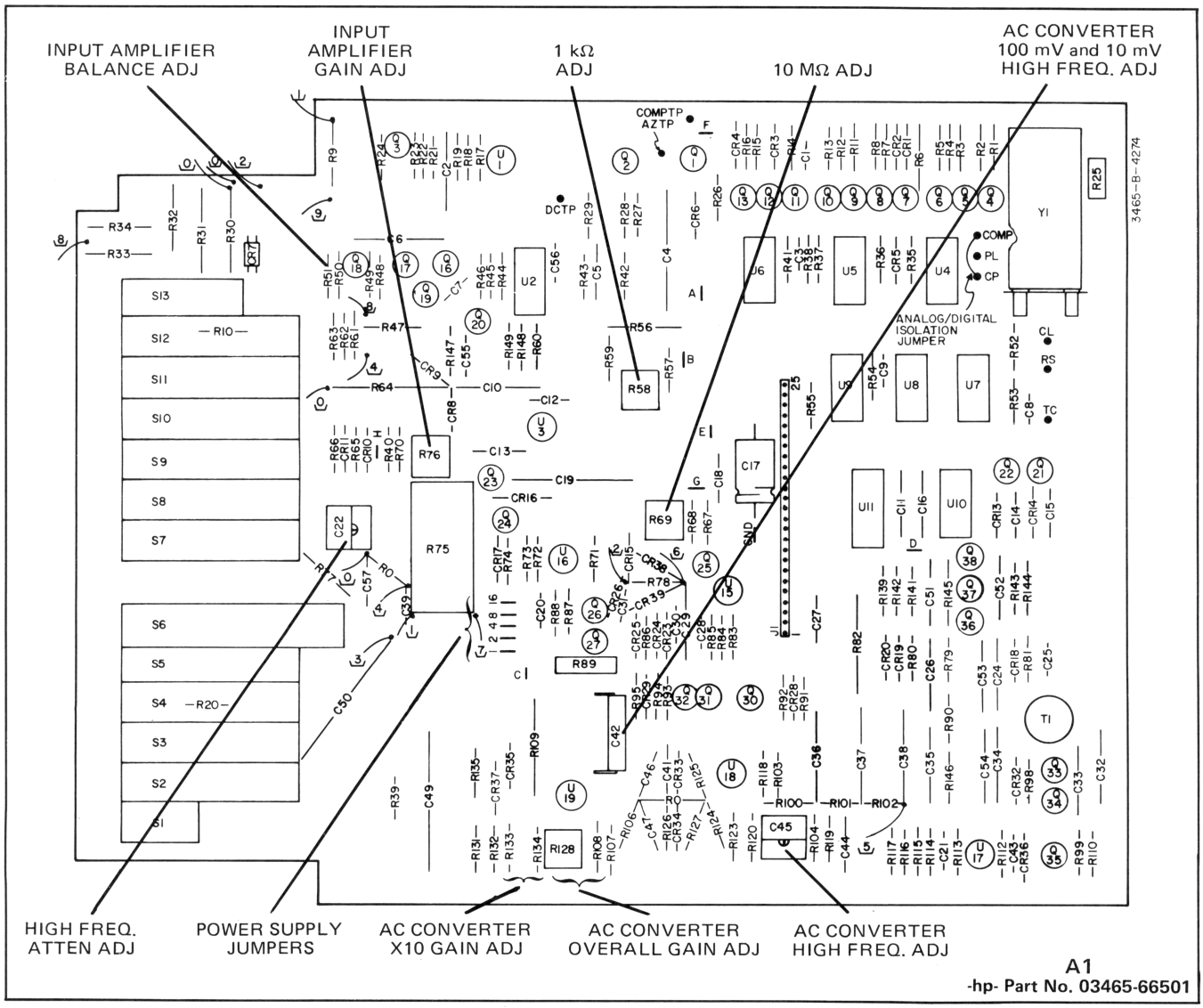

INPUT AMPLIFIER BALANCE ADJ
INPUT AMPLIFIER GAIN ADJ
1 kΩ ADJ
10 MΩ ADJ
AC CONVERTER 100 mV and 10 mV HIGH FREQ. ADJ
HIGH FREQ. ATTEN ADJ
POWER SUPPLY JUMPERS
AC CONVERTER X10 GAIN ADJ
AC CONVERTER OVERALL GAIN ADJ
AC CONVERTER HIGH FREQ. ADJ
ANALOG/DIGITAL ISOLATION JUMPER
A1
-hp- Part No. 03465-66501

Figure 5-8. Multimeter Adjustment Location.

5-26. Power Supply Adjustment.

5-27. Power Supply + 10 V Reference Voltage Adjustment. Coarse adjustment of the + 10 V reference voltage is made by selecting the proper combination of power supply jumpers designated 1, 2, 4, 8 and 16. Coarse adjustment is necessary whenever the + 10 V reference cannot be adjusted with A1R89 (+ 10 V ADJ - fine adjustment) to obtain a display of 1.0000 for a 1 V dc input. This can occur after replacement of A1CR17, A1R75 or A1U16 or because of the long-term drift of the A1CR17 zener voltage.

5-28. Power supply jumpers 1, 2, 4, 8 and 16 parallel resistors in A1R75 which are used as a regulator feedback network. Removing a jumper decreases the + 10 V reference voltage and results in an increase in the Multimeter display for a given input. Clockwise rotation of the + 10 V ADJ, A1R89 (fine adjustment), also results in an increase in the Multimeter display for a given input.

5-29. A DC Standard is required for this adjustment.

a. Set Multimeter function to DCV (⎓ V) and range to 1 V.

b. Connect A1R75 pin 22 to ground.

c. Apply + 1 V dc from the DC Standard between the VΩ and COM terminals.

d. Note and record the Multimeter display.

e. Refer to Table 5-8, Power Supply Jumpers. Locate the line with LO and HI reading limits that bound the Multimeter display recorded and note the jumper combination. (If reading is out of range of table, check A1CR17 for 6.95 V ± 0.25 V, A1R75 and A1U16).

f. A "0" means to remove jumper; a "1" means leave jumper in place. Introduce the jumper combination noted in Step e.

g. Remove the connection from R75 pin 22 to ground.

h. Adjust A1R89 (+ 10 V ADJ) for a Multimeter display of + 1.0000 ± 2 counts.

NOTE

If a display of + 1.0000 cannot be attained with A1R89 after installing the proper jumper combination, a new jumper combination must be selected. If the + 1.0000 display is low, install the jumper combination from the line in Table 5-8 preceeding the jumper combination installed. If the + 1.0000 display is high, install the jumper combination from the line in Table 5-8 succeeding the jumper combination installed.

Table 5-8. Power Supply Jumpers.

READING		POWER SUPPLY JUMPER				
LO	HI	16	8	4	2	1
NOTE 1	.8961	0	0	0	0	0
.8962	.8984	0	0	0	0	1
.8985	.9008	0	0	0	1	0
.9009	.9032	0	0	0	1	1
.9033	.9057	0	0	1	0	0
.9058	.9082	0	0	1	0	1
.9083	.9108	0	0	1	1	0
.9109	.9134	0	0	1	1	1
.9135	.9161	0	1	0	0	0
.9162	.9189	0	1	0	0	1
.9190	.9217	0	1	0	1	0
.9218	.9245	0	1	0	1	1
.9246	.9274	0	1	1	0	0
.9275	.9304	0	1	1	0	1
.9305	.9335	0	1	1	1	0
.9336	.9366	0	1	1	1	1
.9367	.9397	1	0	0	0	0
.9398	.9430	1	0	0	0	1
.9431	.9463	1	0	0	1	0
.9464	.9497	1	0	0	1	1
.9498	.9532	1	0	1	0	0
.9533	.9568	1	0	1	0	1
.9569	.9604	1	0	1	1	0
.9605	.9641	1	0	1	1	1
.9642	.9680	1	1	0	0	0
.9681	.9719	1	1	0	0	1
.9720	.9759	1	1	0	1	0
.9760	.9800	1	1	0	1	1
.9801	.9843	1	1	1	0	0
.9844	.9886	1	1	1	0	1
.9887	.9930	1	1	1	1	0
.9931	NOTE 2	1	1	1	1	1

"0" = Remove Jumper
"1" = Leave Jumper In Place

NOTE 1. For Readings less than .8922, adjustment cannot be made. Check A1CR17 zener voltage for 6.95 V ± 0.25 V.

NOTE 2. Adjustment cannot be made for readings greater than 1.0000. Check A1CR17 zener voltage for 6.95 V ± 0.25 V.

5-30. Input Amplifier Adjustments.

5-31. Input Amplifier Gain Adjustment (R76). A DC Standard is required for this adjustment.

a. Set the Multimeter function to DCV (⎓ V) and range to 10 m.

b. Connect a short across the input terminals (VΩ and COM) and adjust the Multimeter display for 0.000 with R25 (rear panel ZERO ADJ).

c. Remove the short from the input terminals and apply + 10 mV to the input terminals from the DC Standard.

d. Adjust R76 (INPUT AMP GAIN ADJ) for a Multimeter display of + 10.000 ± 3 counts.

5-32. Input Amplifier Balance Adjustment (R50/R51 potentiometer). The input amplifier balance adjustment must be performed if A1Q16, A1U1 or A1R75 are replaced. A Digital Voltmeter is required for this adjustment.

a. Set Multimeter function to DCV (⎓ V) and range to 1 V.

b. Connect ground to the gate of A1Q16 at the junction of A1C7.

c. Connect the Digital Voltmeter to DCTP.

d. Adjust R50/R51 for a Digital Voltmeter reading at DCTP of less than 1 mV.

5-33. Ohms Converter Adjustments (R58 and R69).

5-34. A Digital Voltmeter, a 1 kΩ ± 1% resistor -hp- Part No. 0727-0751 and a 10 MΩ ± 1% resistor, -hp- Part No. 0698-5049 are required for this adjustment.

a. Set Multimeter function to OHMS (Ω) and range to 1K.

b. Short the Multimeter input terminals (VΩ and COM).

c. Connect Digital Voltmeter to junction of A1R78 and A1Q25 gate.

d. Adjust A1R69 (10 MΩ ADJ) for a Digital Voltmeter reading of < 0.5 mV.

e. Remove the input short and the Digital Voltmeter.

f. Put a 1 kΩ ± 1% resistor across the input terminals and adjust A1R58 (1 kΩ ADJ) for Multimeter display of 1.0000 ± 2 counts. If R58 does not have enough range to achieve this display, cut jumper B to introduce A1R57 and readjust A1R58 for the 1.0000 ± 2 count display.

g. Change Multimeter range to 10 M.

h. Remove the 1 kΩ resistor at the input terminals and apply a 10 MΩ ± 1% resistor across the input terminals. Adjust A1R69 for a display of 10.000 ± 3 counts.

i. Remove the 10 MΩ resistor at the input and change range to 1K.

j. Repeat Steps f, g, h and i (1 kΩ ADJ and 10 MΩ ADJ) until both adjustment specifications of Steps f and h are met.

NOTE

If the A1 Assembly switch shield (component side) has been removed, the ac-to-dc converter must be recalibrated by readjusting C45, C42 and C22 with the shield replaced.

5-35. AC – DC Converter Adjustments.

5-36. AC Overall Gain Adjustment (R107*, R108* and R128).

NOTE

The selection of a new resistance value of R107 and R108* should be performed* **ONLY if** *the AC Converter amplifier, A1U18, is replaced. If A1U18 has not been replaced, the AC Overall Gain Adjustment can be made by performing Steps a, k, l and m which adjust A1R128 only.*

A digital Voltmeter with 5 digit resolution, an Ohmmeter and an AC Standard are required for this adjustment.

a. Set Multimeter function ACV (~ V) and range to 1 V.

b. Remove one end of A1R107 from the pc board and connect A1U2 pin 8 to ground.

c. Apply a 1 V, 200 Hz signal from the AC Standard at the junction of A1R106 and A1R107*.

d. Measure and record the dc voltage at DCTP. Designate this reading V_1.

e. Decrease the AC Standard output to 0.1 V, 200 Hz.

f. Measure and record the dc voltage at DCTP. Designate this reading V_2.

g. Calculate the AC Converter constant (CONST):

$$\text{CONST} = \frac{V_1 - V_2}{0.9}$$

h. Disconnect the AC Standard and disconnect one end of R106 from the pc board. Measure and record the actual resistance value of R106.

i. Calculate and record the R107*, R108* resistance total:

(R107* + R108*) = R106 (0.9995 x CONST -1) -500

j. Select a resistance combination for R107* and R108* nearest the (R107* + R108*) calculated value from the R107*, R108*, R133* and R134* Padding List located in the miscellaneous parts list of Section VI. Install the selected resistors.

k. Apply a 1 V, 200 Hz signal from the AC Standard to the Multimeter input terminals.

l. Adjust A1R128 (AC GAIN ADJ) for a Multimeter display of 1.0000 ± 12 counts.

m. Remove the AC Standard.

5-37. AC–DC Converter X10 Gain Adjustment (R133 and R134). An AC Standard is required for this adjustment.

a. Set the Multimeter function to ACV (~ V) and range to 100 m.

b. Apply a 100 mV, 200 Hz signal from the AC Standard to the Multimeter input terminals (VΩ and COM).

c. Adjust the R133/R134 potentiometer for a Multimeter display of 100.00 ± 12 counts.

5-38. AC Converter High Frequency Adjustment (C45). An AC Standard is required for this adjustment.

a. Set Multimeter function to ACV (~ V) and range to 1 V.

b. Apply a 0.1 V, 20 kHz signal with the AC Standard to the input terminals.

c. Adjust A1C45 (CONVERTER HIGH FREQ ADJ) for a Multimeter display of .1000 ± 100 counts.

d. Maintain the AC Standard for the following adjustment.

5-39. AC Converter 100 mV and 10 V High Frequency Adjustment (C42). An AC Standard is required for this adjustment.

a. Set Multimeter function to ACV (~ V) and range to 100 m.

b. Apply a 0.1 V, 20 kHz signal with the AC Standard to the input terminals.

c. Adjust A1C42 (100 mV and 10 V HIGH FREQ ADJ) for a Multimeter display of 100.00 ± 100 counts.

d. Maintain the AC Standard for the following adjustment.

5-40. High Frequency Attenuator Adjustment (C22). An AC Standard is required for this adjustment.

a. Set Multimeter function fo ACV (~ V) and range to 10 V.

b. Apply a 10 V, 20 kHz signal with the AC Standard to the input terminals.

c. Adjust A1C22 (HIGH FREQ ATTEN ADJ) for a Multimeter display of 10.000 ± 100 counts.

d. Remove AC Standard from input terminals.

PERFORMANCE TEST CARD

Hewlett-Packard Model 3465A
Multimeter
Serial No. _____

Tests Performed By _____
Date _____

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-6	DC Voltmeter Accuracy		
	10 mV Range		
	1 mV	.998 – 1.002 mV	_____
	5 mV	4.996 – 5.004 mV	_____
	10 mV	9.995 – 10.005 mV	_____
	100 mV Range		
	10 mV	9.99 – 10.01 mV	_____
	50 mV	49.98 – 50.02 mV	_____
	100 mV	99.97 – 100.03 mV	_____
	1 V Range		
	0.1 V	.0999 – .1001 V	_____
	0.5 V	.4998 – .5002 V	_____
	1.0 V	.9997 – 1.0003 V	_____
	10 V Range		
	1 V	.999 – 1.001 V	_____
	5 V	4.998 – 5.002 V	_____
	10 V	9.997 – 10.003 V	_____
	100 V Range		
	10 V	9.99 – 10.01 V	_____
	50 V	49.98 – 50.02 V	_____
	100 V	99.97 – 100.03 V	_____
	1000 V Range		
	100 V	99.8 – 100.2 V	_____
	500 V	499.7 – 500.3 V	_____
	1000 V	999.6 – 1000.4 V	_____
5-8	DC Ammeter Accuracy		
	100 μA Range		
	10 μA	9.98 – 10.02 μA	_____
	50 μA	49.95 – 50.05 μA	_____
	100 μA	99.92 – 100.08 μA	_____
	1 mA Range		
	0.1 mA	.0998 – .1002 μA	_____
	0.5 mA	.4995 – .5005 μA	_____
	1.0 mA	.9992 – 1.0008 μA	_____
	10 mA Range		
	1 mA	0.998 – 1.002 mA	_____
	5 mA	4.993 – 5.007 mA	_____
	10 mA	9.988 – 10.012 mA	_____

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-8 (cont'd)	100 mA Range		
	10 mA	09.93 – 10.07 mA	_____
	50 mA	49.69 – 50.31 mA	_____
	100 mA	99.39 – 100.61 mA	_____
	1000 mA Range		
	100 mA	099.3 – 100.7 mA	_____
	500 mA	496.9 – 503.1 mA	_____
	1000 mA	993.9 – 1006.1 mA	_____
5-10	Ohms Accuracy		
	100 Ω Range		
	10 Ω	09.98 – 010.02 Ω	_____
	50 Ω	49.97 – 50.03 Ω	_____
	100 Ω	99.96 – 100.04 Ω	_____
	1 kΩ Range		
	0.1 kΩ	.0999 – .1001 kΩ	_____
	0.5 kΩ	.4998 – .5002 kΩ	_____
	1 kΩ	.9997 – 1.0003 kΩ	_____
	10 kΩ Range		
	1 kΩ	.999 – 1.001 kΩ	_____
	5 kΩ	4.998 – 5.002 kΩ	_____
	10 kΩ	9.997 – 10.003 kΩ	_____
	100 kΩ Range		
	10 kΩ	9.99 – 10.01 kΩ	_____
	50 kΩ	49.98 – 50.02 kΩ	_____
	100 kΩ	99.97 – 100.03 kΩ	_____
	1000 kΩ Range		
	100 kΩ	99.9 – 100.1 kΩ	_____
	500 kΩ	499.8 – 500.2 kΩ	_____
	1000 kΩ	999.7 – 1000.3 kΩ	_____
	10 MΩ Range		
	1 MΩ	0.998 – 1.002 MΩ	_____
	5 MΩ	4.994 – 5.006 MΩ	_____
	10 MΩ	9.989 – 10.011 MΩ	_____

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-12	AC Voltage Accuracy		
	100 mV Range		
	40 Hz to 10 kHz		
	10 mV	9.93 – 10.07 mV	_____
	50 mV	49.87 – 50.13 mV	_____
	100 mV	99.80 – 100.20 mV	_____
	10 kHz – 20 kHz		
	10 mV	9.80 – 10.20 mV	_____
	50 mV	49.60 – 50.40 mV	_____
	100 mV	99.35 – 100.65 mV	_____
	1 V Range		
	40 Hz – 10 kHz		
	0.1 V	.0993 – .1007 V	_____
	0.5 V	.4987 – .5013 V	_____
	1.0 V	.9980 – 1.0020 V	_____
	10 kHz – 20 kHz		
	0.1 V	.0980 – .1020 V	_____
	0.5 V	.4960 – .5040 V	_____
	1.0 V	.9935 – 1.0065 V	_____
	10 V Range		
	40 Hz – 10 kHz		
	1 V	.993 – 1.007 V	_____
	5 V	4.987 – 5.013 V	_____
	10 V	9.980 – 10.020 V	_____
	10 kHz – 20 kHz		
	1 V	980 – 1.020 V	_____
	5 V	4.960 – 5.040 V	_____
	10 V	9.935 – 10.065 V	_____
	100 V Range		
	40 Hz – 10 kHz		
	10 V	9.93 – 10.07 V	_____
	50 V	49.87 – 50.13 V	_____
	100 V	99.80 – 100.20 V	_____
	10 kHz – 20 kHz		
	10 V	9.80 – 10.20 V	_____
	50 V	49.60 – 50.40 V	_____
	100 V	99.35 – 100.65 V	_____
	1000 V Range		
	40 Hz – 1 kHz		
	100 V	99.3 – 100.7 V	_____
	500 V	498.7 – 501.3 V	_____
	1 kHz – 2 kHz		
	100 V	99.0 – 101.0 V	_____
	500 V	497.0 – 503.0 V	_____

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-14	AC Ammeter Accuracy		
	100 μA Range		
	10 μA		
	40 Hz – 1 kHz	9.91 – 10.09 μA	_____
	1 kHz – 10 kHz	9.92 – 10.08 μA	_____
	10 kHz – 20 kHz	9.79 – 10.21 μA	_____
	50 μA		
	40 Hz – 1 kHz	49.75 – 50.25 μA	_____
	1 kHz – 10 kHz	49.82 – 50.18 μA	_____
	10 kHz – 20 kHz	49.55 – 50.45 μA	_____
	100 μA		
	40 Hz – 1 kHz	99.55 – 100.45 μA	_____
	1 kHz – 10 kHz	99.70 – 100.30 μA	_____
	10 kHz – 20 kHz	99.25 – 100.75 μA	_____
	1 mA Range		
	0.1 mA		
	40 Hz – 1 kHz	.0991 – .1009 mA	_____
	1 kHz – 10 kHz	.0992 – .1008 mA	_____
	10 kHz – 20 kHz	.0979 – .1021 mA	_____
	0.5 mA		
	40 Hz – 1 kHz	.4975 – .5025 mA	_____
	1 kHz – 10 kHz	.4982 – .5018 mA	_____
	10 kHz – 20 kHz	.4955 – .5045 mA	_____
	1.0 mA		
	40 Hz – 1 kHz	.9955 – 1.0045 mA	_____
	1 kHz – 10 kHz	.9970 – 1.0030 mA	_____
	10 kHz – 20 kHz	.9925 – 1.0075 mA	_____
	10 mA Range		
	1 mA		
	40 Hz – 1 kHz	.991 – 1.009 mA	_____
	1 kHz – 10 kHz	.992 – 1.008 mA	_____
	10 kHz – 20 kHz	.979 – 1.021 mA	_____
	5 mA		
	40 Hz – 1 kHz	4.975 – 5.025 mA	_____
	1 kHz – 10 kHz	4.982 – 5.018 mA	_____
	10 kHz – 20 kHz	4.955 – 5.045 mA	_____
	10 mA		
	40 Hz – 1 kHz	9.955 – 10.045 mA	_____
	1 kHz – 10 kHz	9.970 – 10.030 mA	_____
	10 kHz – 20 kHz	9.925 – 10.075 mA	_____
	100 mA Range		
	10 mA	9.87 – 10.13 mA	_____

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-14 (cont'd)	50 mA	49.55 – 50.45 mA	_____
	100 mA	99.15 – 100.85 mA	_____
	1000 mA Range		
	100 mA	98.7 – 101.3 mA	_____
	500 mA	495.5 – 504.5 mA	_____
	1000 mA	991.5 – 1008.5 mA	_____
5-15	Normal Mode Rejection	< .007 V (60 dB)	_____
5-17	Common Mode Rejection	< .00001 V (120 dB)	_____
5-20	DC Input Resistance		
	10 V – 1000 V Range	4.950 – 5.027 (10 M)	_____
	10 mV – 1 V Range	$\geqslant$ .9990 (10^{10} ohms)	_____
5-22	Input Impedance		
	Resistive component	.4950 – .5027	_____
	Shunt capacitance	.7071 – 1.0000	_____

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION.

6-2. This section contains information for ordering replacement parts. Table 6-3 lists parts in alphameric order of their reference designators and indicates the description, -hp- Part Number of each part, together with any applicable notes, and provides the following:

a. Total quantity used in the instrument (Qty column). The total quantity of a part is given the first time the part number appears.

b. Description of the part. (See list of abbreviations in Table 6-1.)

c. Typical manufacturer of the part is a five-digit code. (See Table 6-2 for list of manufacturers.)

d. Manufacturer's part number.

6-3. Miscellaneous parts are listed in Table 6-3 following their respective assemblies. General miscellaneous parts are listed at the conclusion of Table 6-3.

6-4. ORDERING INFORMATION.

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office. (See Appendix A for list of office locations.) Identify parts by their Hewlett-Packard part numbers. Include instrument model and serial numbers.

6-6. NON-LISTED PARTS.

6-7. To obtain a part that is not listed, include:

a. Instrument model number.
b. Instrument serial number.
c. Description of the part.
d. Function and location of the part.

6-8. PARTS CHANGES.

6-9. Components which have been changed are so marked by one of three symbols; i.e., Δ, Δ with a letter subscript, e.g., Δ_a, or Δ with a number subscript, e.g., Δ_{10}. A Δ with no subscript indicates the component listed is the preferred replacement for an earlier component. A Δ with a letter subscript indicates a change which is explained in a note at the bottom of the page. A Δ with a number subscript indicates the related change is discussed in backdating (Section VIII). The number of the subscript indicates the number of the change in backdating which should be referred to.

6-10. PROPRIETARY PARTS.

6-11. Items marked by a dagger (†) in the reference designator column are available only for repair and service of Hewlett-Packard instruments.

Table 6-1. Standard Abbreviations.

ABBREVIATIONS

Ag .....silver	Hz .....hertz (cycle(s) per second)	NPO .....negative positive zero (zero temperature coefficient)	sl .....slide
Al .....aluminum			SPDT .....single-pole double-throw
A .....ampere(s)	ID .....inside diameter	ns .....nanosecond(s) = 10^{-9} seconds	SPST .....single-pole single-throw
Au .....gold	impg .....impregnated	nsr .....not separately replaceable	
	incd .....incandescent		Ta .....tantalum
C .....capacitor	ins .....insulation(ed)	Ω .....ohm(s)	TC .....temperature coefficient
cer .....ceramic		obd .....order by description	TiO_2 .....titanium dioxide
coef .....coefficient	kΩ .....kilohm(s) = 10^{+3} ohms	OD .....outside diameter	tog .....toggle
com .....common	kHz .....kilohertz = 10^{+3} hertz		tol .....tolerance
comp .....composition		p .....peak	trim .....trimmer
conn .....connection	L .....inductor	pA .....picoampere(s)	TSTR .....transistor
	lin .....linear taper	pc .....printed circuit	
dep .....deposited	log .....logarithmic taper	pF .....picofarad(s) 10^{-12} farads	V .....volt(s)
DPDT .....double-pole double-throw		piv .....peak inverse voltage	vacw .....alternating current working voltage
DPST .....double-pole single-throw	mA .....milliampere(s) = 10^{-3} amperes	p/o .....part of	var .....variable
	MHz .....megahertz = 10^{+6} hertz	pos .....position(s)	vdcw .....direct current working voltage
elect .....electrolytic	MΩ .....megohm(s) - 10^{+6} ohms	poly .....polystyrene	
encap .....encapsulated	met flm .....metal film	pot .....potentiometer	W .....watt(s)
	mfr .....manufacturer	p-p .....peak-to-peak	w/ .....with
F .....farad(s)	ms .....millisecond	ppm .....parts per million	wiv .....working inverse voltage
FET .....field effect transistor	mtg .....mounting	prec .....precision (temperature coeffient, long term stability and/or tolerance)	w/o .....without
fxd .....fixed	mV .....millivolt(s) = 10^{-3} volts		ww .....wirewound
	μF .....microfarad(s)		
GaAs .....gallium arsenide	μs .....microsecond(s)	R .....resistor	
GHz .....gigahertz = 10^{+9} hertz	μV .....microvolt(s) = 10^{-6} volts	Rh .....rhodium	
gd .....guard(ed)	my .....Mylar®	rms .....root-mean-square	* .....optimum value selected at factory, average value shown (part may be omitted)
Ge .....germanium		rot .....rotary	
gnd .....ground(ed)	nA .....nanoampere(s) = 10^{-9} amperes		** .....no standard type number assigned selected or special type
	NC .....normally closed	Se .....selenium	
H .....henry(ies)	Ne .....neon	sect .....section(s)	® Dupont de Nemours
Hg .....mercury	NO .....normally open	Si .....silicon	

DESIGNATORS

A .....assembly	FL .....filter	Q .....transistor	TS .....terminal strip
B .....motor	HR .....heater	QCR .....transistor-diode	U .....microcircuit
BT .....battery	IC .....integrated circuit	R .....resistor	V .....vacuum tube, neon bulb, photocell, etc.
C .....capacitor	J .....jack	RT .....thermistor	W .....cable
CR .....diode	K .....relay	S .....switch	X .....socket
DL .....delay line	L .....inductor	T .....transformer	XDS .....lampholder
DS .....lamp	M .....meter	TB .....terminal board	XF .....fuseholder
E .....misc electronic part	MP .....mechanical part	TC .....thermocouple	Y .....crystal
F .....fuse	P .....plug	TP .....test point	Z .....network

Table 6-2. Code List of Manufacturers.

MFR NO.	MANUFACTURER'S CODE LIST	ADDRESS	
00000	U.S.A. COMMON	ANY SUPPLIER OF USA	
00160	OHARA METAL PRODUCTS	SAN FRANCISCO CAL	94107
01121	ALLEN BRADLEY CO.	MILWAUKEE WI	53212
01295	TEXAS INSTRUMENT INC. SEMICONDUCTOR CMPNT DIV.	DALLAS TX	75231
01686	RCL ELECTRONICS INC.	MANCHESTER NH	03102
02735	RCA CORP. SOLID STATE DIV.	SOMMERVILLE NJ	08876
03888	PYROFILM CORP.	WHIPPANY NJ	07981
04713	MOTOROLA SEMICONDUCTOR PRODUCTS	PHOENIX AZ	85008
12954	DICKSON ELECTRONICS CORP.	SCOTTSDALE AZ	85252
14140	EDISON ELEK DIV MCGRAW–EDISON	MANCHESTER NH	03130
16299	CORNING GLASS WORKS ELEC CMPNT DIV.	RALEIGH NC	27604
17856	SILICONIX INC.	SANTA CLARA CA	95050
19701	MEPCO/ELECTRA CORP.	MINERAL WELLS TX	76067
24546	CORNING GLASS WORKS (BRADFORD)	BRADFORD PA	16701
27014	NATIONAL SEMICONDUCTOR CORP.	SANTA CLARA CA	95051
28480	HEWLETT–PACKARD CO. CORPORATE HQ	PALO ALTO CA	94304
32997	BOURNS INC TRIMPOT PROD DIV.	RIVERSIDE CA	92707
56289	SPRAGUE ELECTRIC CO.	NORTH ADAMS NA	01247
71400	BUSSMAN MFG DIV OF MCGRAW–EDISON CO.	ST LOUIS MO	63017
72136	ELECTRO MOTIVE MFG CO., INC.	WILLIMANTIC CT	06226
73138	BECKMAN INSTRUMENTS INC HELIPOT DIV.	FULLERTON CA	92634
74970	JOHNSON E. F. CO.	WASECA MN	56093
84411	TRW CAPACITOR DIV	OGALLALA NE	69153
91506	AUGAT INC	ATTLEBORO MA	02703
95121	QUALITY COMPONENTS INC	ST MARYS PA	15857
98291	SEALECTRO CORP.	MAMARONECK NY	10544

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A1	03465-66501	1	P.C. ASSEMBLY, MAIN	28480	03465-66501
A1C1	0140-0149	1	CAPACITOR-FXD 470PF +-5% 300WVDC MICA	72136	DM15F471J0300WV1CR
A1C2	0180-0374	1	CAPACITOR-FXD; 10UF+-10% 20VDC TA-SOLID	56289	150D106X9020B2
A1C3	0150-0071	3	CAPACITOR-FXD 400PF +-5% 1000WVDC CER	28480	0150-0071
A1C4	0160-0320	1	CAPACITOR-FXD .33UF +-10% 100WVDC POLYE	84411	663UW33491W
A1C5	0180-1743	1	CAPACITOR-FXD; .1UF+-10% 35VDC TA-SOLID	56289	150D104X9035A2
A1C6	0160-0165	1	CAPACITOR-FXD .056UF +-10% 200WVDC POLYE	56289	292P56392
A1C7	0160-2207	1	CAPACITOR-FXD 300PF +-5% 300WVDC MICA	28480	0160-2207
A1C8	0150-0071		CAPACITOR-FXD 400PF +-5% 1000WVDC CER	28480	0150-0071
A1C9	0150-0071		CAPACITOR-FXD 400PF +-5% 1000WVDC CER	28480	0150-0071
A1C10	0170-0055	1	CAPACITOR-FXD .1UF +-20% 200WVDC POLYE	56289	292P10402
A1C11	0170-0024	1	CAPACITOR-FXD .022UF +-20% 200WVDC POLYE	56289	292P22302
A1C12	0160-2204	1	CAPACITOR-FXD 100PF +-5% 300WVDC MICA	28480	0160-2204
A1C13	0160-0763	1	CAPACITOR-FXD 5PF +-10% 500WVDC MICA	28480	0160-0763
A1C14	0150-0121	2	CAPACITOR-FXD .1UF +80-20% 50WVDC CER	28480	0150-0121
A1C15	0150-0121		CAPACITOR-FXD .1UF +80-20% 50WVDC CER	28480	0150-0121
A1C16	0160-0161	1	CAPACITOR-FXD .01UF +-10% 200WVDC POLYE	56289	292P10392
A1C17	0180-0061	1	CAPACITOR-FXD; 100UF+75-10% 16VDC AL	56289	30D107G016DC2
A1C18	0180-0210	1	CAPACITOR-FXD; 3.3UF+-20% 15VDC TA	56289	150D335X0015A2
A1C19	0160-4347	1	CAPACITOR-FXD 0.44 UF 0.10%	28480	0160-4347
A1C20	0160-2205	2	CAPACITOR-FXD 120PF +-5% 300WVDC MICA	28480	0160-2205
A1C21	0160-0362	1	CAPACITOR-FXD 510PF +-5% 300WVDC MICA	28480	0160-0362
A1C22	0212-0128	1	CAPACITOR; VAR; TRMR; AIR; 1.4/9.2PF	74970	189-0503-005
A1C24	0180-0228	2	CAPACITOR-FXD; 22UF+-10% 15VDC TA-SOLID	56289	150D226X9015B2
A1C25	0140-0207	2	CAPACITOR-FXD 330PF +-5% 500WVDC MICA	72136	DM15F331J0500WV1CR
A1C26	0180-0228		CAPACITOR-FXD; 22UF+-10% 15VDC TA-SOLID	56289	150D226X9015B2
A1C27	0150-0052	1	CAPACITOR-FXD .05UF +-20% 400WVDC CER	28480	0150-0052
A1C28	0160-2605	1	CAPACITOR-FXD .02UF +80-20% 25WVDC CER	28480	0160-2605
A1C29	0160-0157	1	CAPACITOR-FXD 4700PF +-10% 200WVDC POLYE	56289	292P47292
A1C30, C31	0160-0207	2	CAPACITOR-FXD .01UF +-5% 200WVDC	56289	292P10352
A1C32	0180-0566	3	CAPACITOR-FXD; 33UF+-10% 10VDC TA-SOLID	28480	0180-0566
A1C33	0160-0153	1	CAPACITOR-FXD 1000PF +-10% 200WVDC POLYE	56289	292P10292
A1C34, C35	0180-0566		CAPACITOR-FXD; 33UF+-10% 10VDC TA-SOLID	28480	0180-0566
A1C36	0160-0168	3	CAPACITOR-FXD .1UF +-10% 200WVDC POLYE	56289	292P10492
A1C37	0160-0168		CAPACITOR-FXD .1UF +-10% 200WVDC POLYE	56289	292P10492
A1C38	0160-0168		CAPACITOR-FXD .1UF +-10% 200WVDC POLYE	56289	292P10492
A1C39	0160-2046	1	CAPACITOR-FXD 2PF +-.5PF 500WVDC MICA	28480	0160-2046
A1C41	0180-0291	2	CAPACITOR-FXD; 1UF+-10% 35VDC TA-SOLID	56289	150D105X9035A2
A1C42	0121-0427	1	CAPACITOR, VAR, TRMR, MICA, 170/780PF	72136	T52917-6
A1C43	0160-2205		CAPACITOR-FXD 120PF +-5% 300WVDC MICA	28480	0160-2205
A1C44	0180-0291		CAPACITOR-FXD; 1UF+-10% 35VDC TA-SOLID	56289	150D105X9035A2
A1C45	0121-0147		CAPACITOR; VAR; TRMR; AIR; 2/19.3PF	74970	189-507-5
A1C46	0150-0015	2	CAPACITOR-FXD 2.2PF +-10% 500WVDC TI	95121	TYPE QC
A1C47	0150-0015		CAPACITOR-FXD 2.2PF +-10% 500WVDC TI	95121	TYPE QC
A1C48	0140-0207		CAPACITOR-FXD 330PF +-5% 500WVDC MICA	72136	DM15F331J0500WV1CR
A1C49	0160-2115	1	CAPACITOR-FXD 1.3UF +-10% 50WVDC POLYE	56289	149P345
A1C50	0160-3581	1	CAPACITOR-FXD .1UF +-20% 1000WVDC MET	28480	0160-3581
A1C51, C52	0180-0228		CAPACITOR-FXD; 22UF+-10% 15VDC TA-SOLID	56289	150D226X9015B2
A1C53, C54	0180-0566		CAPACITOR-FXD; 33UF+-10% 10VDC TA-SOLID	28480	0180-0566
A1C55 *			SEE PADDING LIST UNDER A1 ASSY MISC PARTS		
A1C56	0150-0093		CAPACITOR-FXD .01UF +80-20% 100WVDC CER	28480	0150-0093
A1C57	0140-0201		CAPACITOR-FXD 12PF +/-5% 500WVDC MICA	72136	DM15C120J0500WV1CR
	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR7	1906-0023	1	DIODE-MULT FULL WAVE BRIDGE RECTIFIER	04713	MDA922-4
A1CR8	1901-0586	2	DIODE-GEN PRP 30V 25MA	28480	1901-0586
A1CR9	1901-0586		DIODE-GEN PRP 30V 25MA	28480	1901-0586
A1CR10	1902-3062	2	DIODE-ZNR 3.92V 5% DO-7 PD=.4W TC=-.049%	04713	SZ 10939-65
A1CR11	1902-3062		DIODE-ZNR 3.92V 5% DO-7 PD=.4W TC=-.049%	04713	SZ 10939-65
A1CR13	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR14	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR15	1901-0376	3	DIODE-GEN PRP 35V 50MA	28480	1901-0376
A1CR16	1901-0376		DIODE-GEN PRP 35V 50MA	28480	1901-0376
A1CR17	1902-1818	1	DIODE-ZNR	28480	1902-1818
A1CR18	1910-0034	2	DIODE-SWITCHING 8NS 30V 80MA	28480	1910-0034
A1CR19	1902-3136	1	DIODE-ZNR 8.06V 5% DO-7 PD=.4W TC=+.052%	04713	SZ 10939-155
A1CR20	1902-3182	3	DIODE-ZNR 12.1V 5% DO-7 PD=.4W TC=+.064%	04713	SZ 10939-206
A1CR23	1902-0057	1	DIODE-ZNR 6.49V 5% DO-7 PD=.4W TC=+.029%	04713	SZ 10939-128
A1CR24	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR25	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR26	1901-0376		DIODE-GEN PRP 35V 50MA	28480	1901-0376
A1CR27 Δ4			NOT ASSIGNED		
A1CR28	1901-0029	1	DIODE-PWR RECT 600V 750MA	28480	1901-0029

See introduction to this section for ordering information

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A1CR29	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR32	1910-0034		DIODE-SWITCHING 8NS 30V 80MA	28480	1910-0034
A1CR33	1901-0518		DIODE-SCHOTTKY	28480	1901-0518
A1CR34	1901-0518		DIODE-SCHOTTKY	28480	1901-0518
A1CR35	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR36	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR37	1901-0040		DIODE-SWITCHING 2NS 30V 50MA	28480	1901-0040
A1CR38, CR39	1901-0376		DIODE-GEN PRP 35V 50MA	28480	1901-0376
A1J1	1251-4109	1	CONNECTOR STRIP-25-PIN	28480	1251-4109
A1L1	9170-0894		CORE-SHIELDING BEAD	02114	56-590-65/4A6
A1Q1	1855-0208	3	TRANSISTOR J-FET 2N4117 N-CHAN D-MODE	17856	2N4117
A1Q2	1855-0308	2	TRANSISTOR-JFET DUAL N-CHAN D-MODE SI	28480	1855-0308
A1Q3	1854-0071	25	TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q4	1853-0086	8	TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q5	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q6	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q7	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q8	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q9	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q10	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q11	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q12	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q13	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q16	1855-0222	1	TRANSISTOR-JFET DUAL D-MODE SI PD=500MW	28480	1855-0222
A1Q17	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q18	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q19	1855-0208		TRANSISTOR J-FET 2N4117 N-CHAN D-MODE	17856	2N4117
A1Q20	1855-0208		TRANSISTOR J-FET 2N4117 N-CHAN D-MODE	17856	2N4117
A1Q21	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q22	1853-0020	2	TRANSISTOR PNP SI PD=300MW FT=150MHZ	28480	1853-0020
A1Q23	1855-0093	2	TRANSISTOR J-FET N-CHAN D-MODE TO-18 SI	28480	1855-0093
A1Q24	1855-0093		TRANSISTOR J-FET N-CHAN D-MODE TO-18 SI	28480	1855-0093
A1Q25	1855-0308		TRANSISTOR-JFET DUAL N-CHAN D-MODE SI	28480	1855-0308
A1Q26	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q27	1853-0020		TRANSISTOR PNP SI PD=300MW FT=150MHZ	28480	1853-0020
A1Q30	1854-0079	1	TRANSISTOR NPN 2N3439 SI TO-5 PD=1W	02735	2N3439
A1Q31	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q32	1853-0086		TRANSISTOR PNP SI PD=310MW FT=40MHZ	28480	1853-0086
A1Q33	1853-0318	1	TRANSISTOR PNP SI PD=500MW FT=60MHZ	04713	MPS6562
A1Q34, Q35	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1Q36, Q37	1853-0020		TRANSISTOR PNP SI PD=300MW FT=150MHZ	28480	1853-0020
A1Q38	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A1R0	8150-3375	2	JUMPER WIRE 22AWG	28480	8150-3375
A1R1	0698-3572	5	RESISTOR 60.4K 1% .125W F TC=0+-100	16299	C4-1/8-T0-6042-F
A1R2	0683-3335	1	RESISTOR 33K 5% .25W FC TC=-400/+800	01121	CB3335
A1R3	0757-0442	1	RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
A1R4	0683-2225	1	RESISTOR 2.2K 5% .25W FC TC=-400/+700	01121	CB2225
A1R5	0683-5635	5	RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A1R6	0757-0344	1	RESISTOR 1M 1% .25W F TC=0+-100	24546	C5-1/4-T0-1004-F
A1R7	0757-0288		RESISTOR 9.09K 1% .125W F TC=0+-100	19701	MF4C1/8-T0-9091-F
A1R8	0683-1045	10	RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R9	0689-3025	1	RESISTOR-FXD 3K OHM 5% 1W	28480	0689-3025
A1R11	0683-2235	1	RESISTOR 22K 5% .25W FC TC=-400/+800	01121	CB2235
A1R12	0683-4725	3	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R13	0757-0449	1	RESISTOR 20K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2002-F
A1R14	0698-4123		RESISTOR 499 1% .125W F TC=0+-100	16299	C4-1/8-T0-499R-F
A1R15	0683-4735	3	RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A1R16	0683-4725		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R17	0683-3025	1	RESISTOR 3K 5% .25W FC TC=-400/+700	01121	CB3025
A1R18	0698-3572		RESISTOR 60.4K 1% .125W F TC=0+-100	16299	C4-1/8-T0-6042-F
A1R19	0698-3572		RESISTOR 60.4K 1% .125W F TC=0+-100	16299	C4-1/8-T0-6042-F
A1R21	0698-3215	1	RESISTOR 499K 1% .125W F TC=0+-100	03888	PME55S
A1R22	0757-0472	3	RESISTOR 200K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2003-F
A1R23	0698-4496	1	RESISTOR 45.3K 1% .125W F TC=0+-100	24546	C4-1/8-T0-4532-F
A1R24	0683-6845	3	RESISTOR 680K 5% .25W FC TC=-800/+900	01121	CB6845
A1R25	2100-3358	1	RESISTOR-VAR TRMR 1MOHM 20% C SIDE ADJ	73138	72XR1M
A1R26	0683-1055	4	RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A1R27	0683-1545	4	RESISTOR 150K 5% .25W FC TC=-800/+900	01121	CB1545
A1R28	0757-0465	2	RESISTOR 100K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1003-F
A1R29	0757-0465		RESISTOR 100K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1003-F
A1R30	0811-3428	1	RESISTOR .1 .5% 4W PW TC=0+-90	28480	0811-3428
A1R31	0811-3427	1	RESISTOR .9 .5% 4W PW TC=0+-90	28480	0811-3427
A1R32	0811-3391	1	RESISTOR 9 .1% .062W PWW TC=0+-10	14140	1274

See introduction to this section for ordering information

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A1R33	0811-3390	1	RESISTOR 90 .05% .031W PWW TC=0+-10	14140	1274
A1R34	0811-3392	1	RESISTOR 900 .05% .031W PWW TC=0+-10	14140	1274
A1R35	0683-3355	3	RESISTOR 3.3M 5% .25W FC TC=-900/+1100	01121	CB3355
A1R36	0683-3355		RESISTOR 3.3M 5% .25W FC TC=-900/+1100	01121	CB3355
A1R37	0683-3355		RESISTOR 3.3M 5% .25W FC TC=-900/+1100	01121	CB3355
A1R38	0683-1035	6	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R39	0698-7332	1	RESISTOR 1M 1% .125W F TC=0+-100	19701	MF5C1/8-TO-1004-F
A1R40	0757-0449		RESISTOR FXD 20K 1%	24546	C4-1/8-TO-2002-F
A1R41	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R42	0698-4539	1	RESISTOR 402K 1% .125W F TC=0+-100	03888	PME55S
A1R43	0698-4541	2	RESISTOR 442K 1% .125W F TC=0+-100	03888	PME55S
A1R44	0683-2745	2	RESISTOR 270K 5% .25W FC TC=-800/+900	01121	CB2745
A1R45	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R46	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R47	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R48	0683-1055		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A1R49	0683-5135	1	RESISTOR 51K 5% .25W FC TC=-400/+800	01121	CB5135
A1R50Δ1	2100-3211		RESISTOR-VAR TRMR 1KOHM 10% C TOP ADJ	73138	72PR1K
A1R51Δ1		1	(THIS ONE POTENTIOMETER INCORPORATE S R50 & R51)		
A1R52	0683-5635		RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A1R53	0683-1245	1	RESISTOR 120K 5% .25W FC TC=-800/+900	01121	CB1245
A1R54	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R55	0683-1815	1	RESISTOR 180 5% .25W FC TC=-400/+600	01121	CB1815
A1R56	0811-2764	1	RESISTOR 99.5K .1% .125W PWW TC=0+-10	14140	1250-1/8-D-9952-B
A1R57	0698-3446	1	RESISTOR 383 1% .125W F TC=0+-100	16299	C4-1/8-T0-383R-F
A1R58	2100-0554	2	RESISTOR-VAR TRMR 500 OHM 10% C TOP ADJ	73138	72PR500
A1R59	0698-4541		RESISTOR 442K 1% .125W F TC=0+-100	03888	PME55S
A1R60	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R61	0683-2405	1	RESISTOR 24 5% .25W FC TC=-400/+500	01121	CB2405
A1R62	0683-1065	1	RESISTOR 10M 5% .25W FC TC=-900/+1100	01121	CB1065
A1R63	0683-1215	9	RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A1R64	0693-1041	2	RESISTOR 100K 10% 2W CC TC=0+882	01121	HB1041
A1R65	0683-1545		RESISTOR 150K 5% .25W FC TC=-800/+900	01121	CB1545
A1R66	0683-9135	1	RESISTOR 91K 5% .25W FC TC=-400/+800	01121	CB9135
A1R67	0683-6845		RESISTOR 680K 5% .25W FC TC=-800/+900	01121	CB6845
A1R68	0757-0462	1	RESISTOR 75K 1% .125W F TC=0+-100	24546	C4-1/8-TO-7502-F
A1R69	2100-0554		RESISTOR-VAR TRMR 500 OHM 10% C TOP ADJ	73138	72PR500
A1R70*			SEE PADDING LIST UNDER A1 ASSY MISC PARTS		
A1R71	0698-8345	1	RESISTOR 634K 1% .125W F TC=0+-100	19701	MF5C1/8-T0-6343-F
A1R72	0757-0472	1	RESISTOR 200K 1% .125W F TC=0+-100	24546	C4-1/8-TO-2003-F
A1R73	0698-4470	1	RESISTOR 6.98K 1% .125W F TC=0+-100	24546	C4-1/8-TO-4991-F
A1R74	0698-3279	1	RESISTOR 4.99K 1% .125W F TC=0+-100	16299	C4-1/8-TO-4991-F
A1R75	T88044	1	FINE LINE ASSEMBLY	28480	T88044
A1R76 Δ1	2100-0558	1	RESISTOR-VAR TRMR 20 KOHM 10% C TOP ADJ	73138	72PR20K
A1R77	0686-1035	1	RESISTOR 10K 5% .5W CC TC=0+765	01121	EB1035
A1R78	0683-4735		RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A1R79	0683-2005	1	RESISTOR 20 5% .25W FC TC=-400/+500	01121	CB2005
A1R80	0683-2225	6	RESISTOR 2.2K 5% .25W FC TC=-400/+700	01121	CB2225
A1R81	0683-3015	4	RESISTOR 300 5% .25W FC TC=-400/+600	01121	CB3015
A1R82	0693-1041		RESISTOR 100K 10% 2W CC TC=0+882	01121	HB1041
A1R83	0683-1025	1	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A1R84	0698-3572		RESISTOR 60.4K 1% .125W F TC=0+-100	16299	C4-1/8-T0-6042-F
A1R85	0698-3572		RESISTOR 60.4K 1% .125W F TC=0+-100	16299	C4-1/8-T0-6042-F
A1R86	0683-4725		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R87	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R88	0683-5125	2	RESISTOR 5.1K 5% .25W FC TC=-400/+700	01121	CB5125
A1R89	2100-3123	1	RESISTOR-VAR TRMR 500 OHM 10% C SIDE ADJ	32997	3006P-1-501
A1R90	0683-2025		RESISTOR 2K 5% .25W FC TC=-400/+700	01121	CB2025
A1R91	0683-4705	1	RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A1R92	0683-1545		RESISTOR 150K 5% .25W FC TC=-800/+900	01121	CB1545
A1R93	0683-2745		RESISTOR 270K 5% .25W FC TC=-800/+900	01121	CB2745
A1R94	0757-0410		RESISTOR 301 1% .125W F TC=0+-100	24546	C4-1/8-T0-301R-F
A1R95	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R98	0683-3015		RESISTOR 300 5% .25W FC TC=-400/+600	01121	CB3015
A1R99	0683-1505	1	RESISTOR 15 5% .25W FC TC=-400/+500	01121	CB1505
A1R100	0698-3456	3	RESISTOR 287K 1% .125W F TC=0+-100	16299	C4-1/8-T0-2873-F
A1R101	0698-3456		RESISTOR 287K 1% .125W F TC=0+-100	16299	C4-1/8-T0-2873-F
A1R102	0698-3456		RESISTOR 287K 1% .125W F TC=0+-100	16299	C4-1/8-T0-2873-F
A1R103	0683-2445	1	RESISTOR 240K 5% .25W FC TC=-800/+900	01121	CB2445
A1R104	0683-2245	1	RESISTOR 220K 5% .25W FC TC=-800/+900	01121	CB2245
A1R106	0698-8203	1	RESISTOR 120K 1% .125W F TC=0+-15	19701	MF4C1/8-T10-1203-F
A1R107*			SEE PADDING LIST UNDER A1 ASSY MISC PARTS		
A1R108*			SEE PADDING LIST UNDER A1 ASSY MISC PARTS		
A1R109	0692-4735	1	RESISTOR 47K 5% 2W CC TC=0+765	01121	HB4735

See introduction to this section for ordering information

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A1R110	0683-2425	1	RESISTOR 2.4K 5% .25W FC TC=-400/+700	01121	CB2425
A1R112	0683-5125		RESISTOR 5.1K 5% .25W FC TC=-400/+700	01121	CB5125
A1R113	0683-4755	1	RESISTOR 4.7M 5% .25W FC TC=-900/+1100	01121	CB4755
A1R114	0698-3149	1	RESISTOR 255K 1% .125W F TC=0+-100	16299	C4-1/8-TO-2553-F
A1R115	0683-6845		RESISTOR 680K 5% .25W FC TC=-800/+900	01121	CB6845
A1R116	0683-1545		RESISTOR 150K 5% .25W FC TC=-800/+900	01121	CB1545
A1R117	0757-0478	1	RESISTOR 365K 1% .125W F TC=0+-100	19701	MF4C1/8-TO-3653-F
A1R118	0698-6871	2	RESISTOR 10K .5% .125W F TC=0+-50	03888	PME55S
A1R119	0683-1055		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A1R120	0683-4735		RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A1R123	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R124	0683-1055		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A1R125	0698-6385	2	RESISTOR 220K 1% .125W F TC=0+-25	03888	PME55S
A1R126	0698-6871		RESISTOR 10K .5% .125W F TC=0+-50	03888	PME55S
A1R127	0698-6385		RESISTOR 220K 1% .125W F TC=0+-25	03888	PME55S
A1R128	2100-3211		RESISTOR-VAR TRMR 1KOHM 10% C TOP ADJ	73138	72PR1K
A1R131	0698-6362	1	RESISTOR 1K .1% .125W F TC=0+-25	24546	NE55
A1R132	0698-8613	1	RESISTOR, FXD 8.97K OHM 0.1% .125W F	28480	0698-8613
A1R133* Δ_1	2100-3383	1	RESISTOR-VAR TRMR 50 OHM 10% C TOP ADJ	73138	72PR50
A1R134* Δ_1			(THIS ONE POTENTIOMETER INCORPORATES R133 & R134)		
A1R135	0683-4745	1	RESISTOR 470K 5% .25W FC TC=-800/+900	01121	CB4745
A1R139	0698-4504		RESISTOR 69.8K 1% .125W F TC=0+-100	24546	C4-1/8-TO-6982-F
A1R140			NOT ASSIGNED		
A1R141	0757-0978		RESISTOR 95.3K 1% .125W F TC=0+-100	24546	C4-1/8-TO-9532-F
A1R142, 43	0683-3335		RESISTOR 33K 5% .25W FC TC=-400/+800	01121	CB3335
A1R144	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R145, 46	0683-4735		RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A1R147	0683-1035		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A1R148	0683-1055		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A1R149	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1T1	9100-0657	1	TRANSFORMER, POWER CONVERTER	28480	9100-0657
A1U1	1826-0310	6	IC, LIN MC3476G AMPL	04713	MC3476G
A1U2	1820-0946	2	IC CD4001AE	02735	CD4001AE
A1U3	1820-0223	1	IC LM301AH	27014	LM301AH
A1U4, U5	1820-0939	3	IC CD4013AE	02735	CD4013AE
A1U6	1820-0949	4	IC CD4011AE	02735	CD4011AE
A1U7	1820-0947	2	IC CD4030AE	02735	CD4030AE
A1U8	1820-0946	1	IC CD4025AE	02735	CD4025AE
A1U9	1820-0946		IC CD4001AE	02735	CD4001AE
A1U10	1820-0947		IC CD4030AE	02735	CD4030AE
A1U11	1820-1239	1	IC MK 5007P	28480	1820-1239
A1U15-U19	1826-0310		IC, LIN MC3476G AMPL	04713	MC3476G
	03465-61602	1	CABLE ASSY, 25-PIN(INCLUDES P2, P3)	28480	03465-61602
A1Y1	0410-0595	1	CRYSTAL, QUARTZ 100KHZ 0.1%	28480	0410-0595
A1A1	03465-61901	1	SWITCH ASSEMBLY	28480	03465-61901
A1A1R10	0757-0273		RESISTOR 3.01K 1% .125W F TC=0+-100	24546	C4-1/8-TO-3011-F
A1A1R20	0757-0472		RESISTOR 200K 1% .125W F TC=0+-100	24546	C4-1/8-TO-2003-F
A1A1S1-S13	3101-1949	1	SWITCH, PUSHBUTTON 14-STATION	28480	3101-1949
A1A1W1	03465-61601	1	CABLE, SWITCH	28480	03465-61601
			A1 ASSEMBLY MISCELLANEOUS PARTS		
	1200-0770	1	SOCKET-XTAL 2-CONT HC-6/U-PKG	28480	1200-0770
	1460-1425	1	SPRING, FUSE	28480	1460-1425
C55*			PADDING LIST FOR C55*		
	0160-0763	1	CAPACITOR:FXD 5PF +/-10% 500WVDC MICA	28480	0160-0763
	0160-0205	1	CAPACITOR:FXD 10PF +/-5% 500WVDC MICA	28480	0160-0205
R70*			PADDING LIST FOR R70*		
	0698-4491	1	RESISTOR:FXD 30.9K .125W	24546	C4-1/8-TO-3092-F
	0698-4504	1	RESISTOR:FXD 69.8K .125W	24546	C4-1/8-TO-6982-F
R107* AND R108*			PADDING LIST FOR R107* AND R108*		
	0683-0515	1	RESISTOR 5.1 5% .25W FC TC=-400/+500	01121	CB51G5
	0757-0346	1	RESISTOR 10 1% .125W F TC=0+-100	24546	C4-1/8-TO-10R0-F
	0757-0378	1	RESISTOR 11 1% .125W F TC=0+-100	19701	MF4C1/8-TO-11R0-F
	0757-0379	1	RESISTOR 12.1 1% .125W F TC=0+-100	19701	MF4C1/8-TO-12R1-F
	0757-0380	1	RESISTOR 13 1% .125W F TC=0+-100	19701	MF4C1/8-TO-13R0-F
	0698-4358	1	RESISTOR 14 1% .125W F TC=0+-100	03888	PME55-1/8-TO-14R0-F
	0757-0381	1	RESISTOR 15 1% .125W F TC=0+-100	19701	MF4C1/8-TO-15R0-F
	0698-0384	1	RESISTOR 20 1% .125W F TC=0+-100	28480	0698-0384
	0757-0291	1	RESISTOR 24.9 1% .125W F TC=0+-100	19701	MF4C1/8-T0-2492-F
	0757-0388	1	RESISTOR 30.1 1% .125W F TC=0+-100	24546	C4-1/8-TO-30R1-F
	0698-4126	1	RESISTOR 35.7 1% .125W F TC=0+-100	16299	C4-1/8-TO-35R7-F
	0698-4123	2	RESISTOR 499 1% .125W F TC=0+-100	16299	C4-1/8-TO-499R-F
	0757-0280	2	RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-TO-1001-F
	0757-0427	1	RESISTOR 1.5K 1% .125W F TC=0+-100	24546	C4-1/8-TO-1501-F

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
	0757-0283	1	RESISTOR 2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2001-F
	0698-4442	1	RESISTOR 4.42K 1% .125W F TC=0+-100	16299	C4-1/8-T0-4421-F
	0757-0439	1	RESISTOR 6.81K 1% .125W F TC=0+-100	24546	C4-1/8-T0-6811-F
	0757-0288	2	RESISTOR 9.09K 1% .125W F TC=0+-100	19701	MF4C1/8-T0-9091-F
	0698-3262	1	RESISTOR 40.2 1% .125W F TC=0+-100	16299	C4-1/8-TO-4022-F
	0757-0277	1	RESISTOR 49.9 1% .125W F TC=0+-100	24546	C4-1/8-T0-4992-F
	0698-4387	1	RESISTOR 60.4 1% .125W F TC=0+-100	16299	C4-1/8-T0-60R4-F
	0698-4391	1	RESISTOR 69.8 1% .125W F TC=0+-100	16299	C4-1/8-T0-69R8-F
	0698-4396	1	RESISTOR 80.6 1% .125W F TC=0+-100	16299	C4-1/8-T0-80R6-F
	0757-0400	1	RESISTOR 90.9 1% .125W F TC=0+-100	24546	C4-1/8-T0-90R9-F
	0757-0401	1	RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
	0757-0407	1	RESISTOR 200 1% .125W F TC=0+-100	24546	C4-1/8-T0-201-F
	0757-0410	2	RESISTOR 301 1% .125W F TC=0+-100	24546	C4-1/8-T0-301R-F
	0698-3445	1	RESISTOR 348 1% .125W F TC=0+-100	16299	C4-1/8-T0-348R-F
	0698-4453	1	RESISTOR 402 1% .125W F TC=0+-100	24546	C4-1/8-T0-402R-F
	0698-3510	1	RESISTOR 453 1% .125W F TC=0+-100	16299	C4-1/8-T0-453R-F
A2	03465-66502	1	P.C. ASSEMBLY,DISPLAY INTERFACE	28480	03465-66502
A2C1	0180-0106	1	CAPACITOR-FXD; 60UF+-20% 6VDC TA-SOLID	56289	150D606X000B2
A2C2	0150-0096	1	CAPACITOR-FXD .05UF +80-20% 100WVDC CER	28480	0150-0096
A2J2	1251-4112	2	CONNECTOR STRIP, 25-PIN	28480	1251-4112
A2P1	1251-4166	1	P.C. BD. CONNECTOR,RECTANGULAR	28480	1251-4166
A2Q1	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q2	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q3	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q4	1853-0016	4	TRANSISTOR PNP SI TO-92 PD=300MW	28480	1853-0016
A2Q5	1855-0081	4	TRANSISTOR J-FET 2N5245 N-CHAN D-MODE SI	01295	2N5245
A2Q6	1853-0016		TRANSISTOR PNP SI TO-92 PD=300MW	28480	1853-0016
A2Q7	1855-0081		TRANSISTOR J-FET 2N5245 N-CHAN D-MODE SI	01295	2N5245
A2Q8	1853-0016		TRANSISTOR PNP SI TO-92 PD=300MW	28480	1853-0016
A2Q9	1855-0081		TRANSISTOR J-FET 2N5245 N-CHAN D-MODE SI	01295	2N5245
A2Q10	1853-0016		TRANSISTOR PNP SI TO-92 PD=300MW	28480	1853-0016
A2Q11	1855-0081		TRANSISTOR J-FET 2N5245 N-CHAN D-MODE SI	01295	2N5245
A2Q12	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q13	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q14	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q15	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q16	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q17	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q18	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q19	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q20	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q21	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2Q22	1854-0547	1	TRANSISTOR NPN 2N3725 SI TO-5 PD=800MW	01295	2N3725
A2Q23	1854-0071		TRANSISTOR NPN SI PD=300MW FT=200MHZ	28480	1854-0071
A2R1	0683-1025	2	RESISTOR 1K 5% .25W FC TC=-400/+700	01121	CB1025
A2R2	0683-5635		RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A2R3	0683-6835	3	RESISTOR 68K 5% .25W FC TC=-400/+800	01121	CB6835
A2R4	0683-1025		RESISTOR 1K 5% .25W FC TC=-400/+700	01121	CB1025
A2R5	0683-5635		RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A2R6	0683-6835		RESISTOR 68K 5% .25W FC TC=-400/+800	01121	CB6835
A2R7	0683-1625		RESISTOR 1.6K 5% .25W FC TC=-400/+700	01121	CB1625
A2R8	0683-5635		RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A2R9	0683-6835		RESISTOR 68K 5% .25W FC TC=-400/+800	01121	CB6835
A2R10	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R11	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R12	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R13	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R14	0683-1045		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R15	0683-2025		RESISTOR 2K 5% .25W FC TC=-400/+700	01121	CB2025
A2R16	0683-2025		RESISTOR 2K 5% .25W FC TC=-400/+700	01121	CB2025
A2R17	0683-2025		RESISTOR 2K 5% .25W FC TC=-400/+700	01121	CB2025
A2R18	0683-2025		RESISTOR 2K 5% .25W FC TC=-400/+700	01121	CB2025
A2R19	0683-2015		RESISTOR 200 5% .25W FC TC=-400/+600	01121	CB2015
A2R20	0683-3035	9	RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R21	0683-2035	10	RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R22	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R23	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R24	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R25	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R26	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R27	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R28	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R29	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R30	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035

Table 6-3. Replaceable Parts

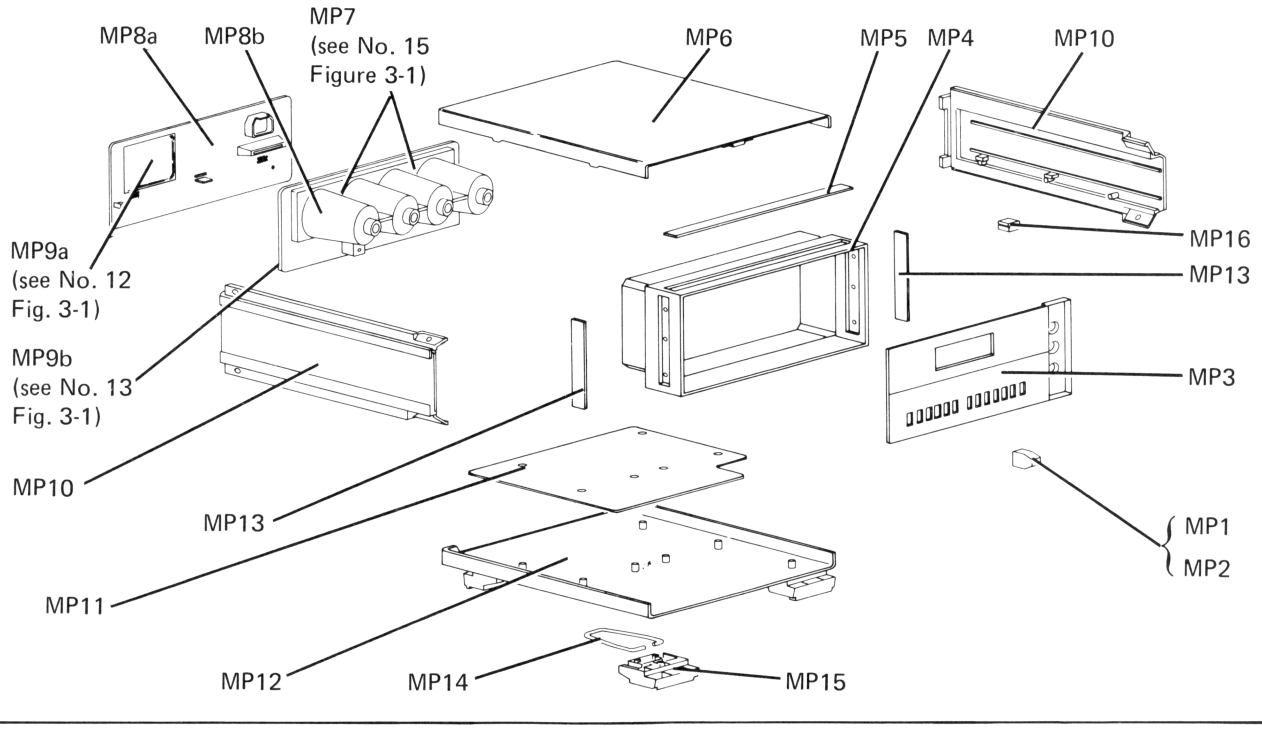
Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A2R31	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R32	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R33	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R34	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R35	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R36	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R37	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R38	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R39	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R40	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R41	0683-3025		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3025
A2R42	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R43	0683-1215		RESISTOR 120 5% .25W FC TC=-400/+600	01121	CB1215
A2R44	0683-3035		RESISTOR 30K 5% .25W FC TC=-400/+800	01121	CB3035
A2R45	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R46	0683-2035		RESISTOR 20K 5% .25W FC TC=-400/+800	01121	CB2035
A2R47	0698-4475		RESISTOR 9.76K 1% .125W F TC=0+-100	03888	PME55-1/8-TO-9761-F
A2R48	0757-0273		RESISTOR 3.01K 1% .125W F TC=0+-100	24546	C4-1/8-TO-3011-F
A2R49	0683-0335		RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB0335
A2R50-R55	0683-2035		RESISTOR 20K 5% .25W FC TC=-400%+800	01121	CB2035
A2U1	1820-0949	1	IC CD4011AE	02735	CD4011AE
A2U2	1820-0950		IC CD4012AE	02735	CD4012AE
A2U3	1820-0949		IC CD4011AE	02735	CD4011AE
A2U4	1820-0939	1	IC CD4013AE	02735	CD4013AE
A2U5	1820-1413		IC MC14511CP	04713	MC14511CP
A2U6	1820-0949		IC CD4011AE	02735	CD4011AE
A5	03465-66505	1	LED DISPLAY ASSEMBLY	28480	03465-66505
A5CR1	1990-0450	1	LED-VISIBLE (SAMPLE RATE)	28480	1990-0450
A5DS1	1990-0532	1	LED DISPLAY 0.3" (POLARITY/OVERRANGE)	28480	1990-0532
A5DS2	1990-0531	4	SEG DISPLAY, 0.3" X 7" (7 SEGMENT)	28480	1990-0531
A5DS3	1990-0531		SEG DISPLAY, 0.3" X 7"	28480	1990-0531
A5DS4	1990-0531		SEG DISPLAY, 0.3" X 7"	28480	1990-0531
A5DS5	1990-0531		SEG DISPLAY, 0.3" X 7"	28480	1990-0531
A5J3	1251-4112		CONNECTOR STRIP- 25PIN	28480	1251-4112
A10	03465-80000	1	STANDARD OR OPTION 001 NI CAD BATTERY ASSEMBLY	28480	03465-80000
A10B1	00035-60024	2	BATTERY PACK ASSEMBLY(STD ONLY)	28480	00035-60024
A10B2	00035-60024		BATTERY PACK ASSEMBLY(STD ONLY)	28480	00035-60024
A10A6	03465-66506	1	PC ASSEMBLY, AC LINE & NI-CAD POWER	28480	03465-66506
A10A6C1	0180-2552	1	CAPACITOR-FXD; 400UF+75-10% 15VDC AL	56289	502D125
A10A6C2	0150-0024		C:FXD .02UF +80-20 600WVDC	71590	DD203-Z5U-+80-20
A10A6CR1	1902-3097	1	DIODE-ZNR 5.23V 2% DO-7 PD=.4W TC=-.003%	12954	DZ7307120
A10A6CR2-CR5	1901-0753	4	DIODE-PWR RECT 400V 750MA	28480	1901-0753
A10A6F1	2110-0311	1	FUSE .062A 250V SLO BLO	75915	313.062S
A10A6Q1	1854-0701	1	TRANSISTOR, NPN MJE2100	28480	1854-0701
A10A6Q2	1853-0374	1	TRANSISTOR PNP TO-18 PD=500MW	28480	1853-0374
A10A6Q3	1853-0394	1	TRANSISTOR, NPN MJE2370	28480	1853-0394
A10A6R1	0684-4711	1	RESISTOR 470 10% .25W FC TC=-400/+600	01121	CB4711
A10A6R2	0684-4721	1	RESISTOR 4.7K 10% .25W FC TC=-400/+700	01121	CB4721
A10A6R3	0683-1005	1	RESISTOR 10 5% .25W	01121	CB1005
A10A6R4	0686-5105	2	RESISTOR 51 5% .5W CC TC=0+412	01121	CB5105
A10A6R5	0686-5105		RESISTOR 51 5% .5W CC TC=0+412	01121	CB5105
A10A6S1	3101-2027	2	SWITCH-PB 1A 300VAC PC	28480	3101-2027
A10A6S2	00035-40026	1	LINE SELECTOR SLIDE SWITCH	28480	00035-40026
A10A6T1	9100-3490	1	TRANSFORMER	28480	9100-3490
			A10 ASSEMBLY MISCELLANEOUS PARTS		
	1460-1426	2	SPRING-CONTACT	28480	1460-1426
	0363-0084	2	CONTACT, SINGLE PIECE SWITCH	00160	OBD
	2110-0269	2	FUSEHOLDER, CLIP TYPE .25 FUSE	91506	6008-32CN
	5000-5086	1	CONTACT, MALE (AC POWER CONNECTOR PINS)	28480	5000-5086
	5000-5087	2	CONTACT, MALE (AC POWER CONNECTOR PIN-GRD)	28480	5000-5087
	5040-7854	1	CAM-LINE PLUG	28480	5040-7854
W2	8120-1348	1	CABLE-AC POWER	28480	8120-1348

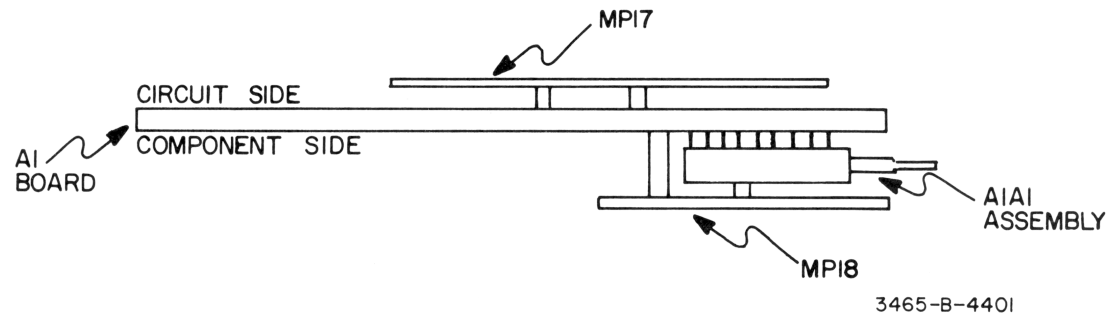
Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A20	03465-80002	1	OPTION 002 ONLY PRI BATTERY ASSEMBLY	28480	03465-80002
A20B1-B4	1420-0224	4	BATTERY CELL "D" 1.5V ("U2 IN EUROPE)	00000	OBD
A20A7	03465-66507	1	PC ASSEMBLY, DRY CELL POWER	28480	03465-66507
A20A7CR1	1902-3182		DIODE-ZNR 12.1V 5% DO-7 PD=.4W TC=+.064%	04713	SZ 10939-206
A20A7CR2	1902-3182		DIODE-ZNR 12.1V 5% DO-7 PD=.4W TC=+.064%	04713	SZ 10939-206
A20A7R1-A20A7R4	0683-2265	4	RESISTOR 22M 5% .25W FC TC=-900/+1200	01121	CB2265
A20A7S1	3101-2027		SWITCH, PUSHBUTTON	28480	3101-2027
			A20 ASSEMBLY MISCELLANEOUS PARTS		
	7185-0086	1	ROD-BRASS	28480	7185-0086
	1460-1428	1	BATTERY CONTACT SPRING	28480	1460-1428
	0363-0108		PIN-CHARGER	00160	OBD
	1460-1426	2	SPRING, CONTACT	28480	1460-1426
			MISCELLANEOUS PARTS GENERAL		
J4, J5	03465-26001	2	INSERT-TERM (V, OHM & COM)	28480	03465-26001
	5040-7843	1	DETENT TERM	28480	5040-7843
	5040-7861	2	PC GUIDE (A2)	28480	5040-7861
	7120-4675	1	DECAL-FRONT PANEL	28480	7120-4675
	03465-26002	1	INSERT-TERMINAL BATTERY	28480	03465-26002
	5040-7928	1	TERMINAL-FUSED CAP (A)	28480	5040-7928
J6	5040-7928	1	TERMINAL-FUSED CAP (A)	28480	03465-26003
	5040-7922	1	LENS, FRONT, RED	28480	5040-7922
	03465-00601	1	SWITCH, SHIELD	28480	03465-00601
W1	03465-61602		CABLE ASSY, 25-PIN(INCLUDES P2, P3)	28480	03465-61602
P2, P3	1251-4113		PC BOARD CONNECTOR-25-PIN	28480	1251-4113
F1	2110-0002	1	FUSE 2A 250V 1.25X.25 IEC (AMPS PROTECTION)	71400	AGC-2
	2360-0372	4	SCREW-MACH PLASTIC	28480	2360-0372

Table 6-3. Replaceable Parts.

REFERENCE DESIGNATOR	-hp- PART NO.	TQ	DESCRIPTION	MFR.	MFR. PART NO.
			MECHANICAL PARTS LIST		
MP1	0370–2625	1	KEY, CAP (WHITE) (OFF/ON)	28480	0370–2625
MP2	0370–2486	12	PUSHBUTTON (SOLID GREY)(FUNC. & RANGE)	28480	0370–2486
MP3	5040–7824	1	FRONT PANEL	28480	5040–7824
MP4	5020–8813	1	FRONT FRAME	28480	5020–8813
MP5	5040–7203	1	TRIM–TOP	28480	5040–7203
MP6	5040–7208	1	TOP COVER	28480	5040–7208
MP7	5040–7852	2	BATTERY ACCESS DOOR LOCK (OPT. 002)	28480	5040–7852
MP8a	T46994	1	REAR PANEL (STD OR OPTION 001)	28480	T46994
MP8b	5040–7850	1	REAR PANEL (OPTION 002 ONLY)	28480	5040–7850
MP9a	5040–7971	1	BATTERY ACCESS DOOR (STD OR OPTION 001)	28480	5040–7971
MP9b	5040–7851	1	BATTERY ACCESS DOOR (OPTION 002 ONLY)	28480	5040–7851
MP10	5040–7212	2	SIDE COVER	28480	5040–7212
MP11	03465–00602	1	BOTTOM SHIELD	28480	03465–00602
MP12	5040–7209	1	BOTTOM COVER	28480	5040–7209
MP13	5001–0438	2	TRIM STRIP	28480	5001–0438
MP14	1460–1345	2	WIREFORM TILT STAND	28480	1460–1345
MP15	5040–7201	4	FOOT	28480	5040–7201
MP16	5040–7970	6	PC BOARD GUIDES	28480	5040–7970
MP17	03465–00603	1	TOP SHIELD	28480	03465–00603
MP18	03465–00601	1	SWITCH SHIELD	28480	03465–00601





SECTION VII
TROUBLESHOOTING AND CIRCUIT DIAGRAMS

7-1. INTRODUCTION.

7-2. This section of the manual contains troubleshooting information, the functional block diagram and circuit diagrams for the Multimeter. The troubleshooting paragraphs are divided into three parts:

1. Preliminary troubleshooting
2. Analog troubleshooting
3. Digital troubleshooting

Additional troubleshooting information is located on the block diagram and individual circuit diagrams in the form of dc voltage levels and notes.

7-3. SCHEMATIC DIAGRAMS.

7-4. The schematic diagrams (Figure 7-2 through Figure 7-5) contained in this section illustrate the circuits of the Multimeter. Components marked with an asterisk are those that are critical in value. Some of these "starred" components are part of an adjustment procedure. A method for selecting the correct value is outlined in the adjustment procedures of Section V, if service in these circuit areas is required.

WARNING

Maintenance procedures of Sections V and VII are intended for qualified service personnel only. To reduce the possibility of electrical shock, only qualified personnel are to perform maintenance duties.

7-5. PRELIMINARY TROUBLESHOOTING.

7-6. Preliminary troubleshooting consists of verifying the + 11 V, + 10 V reference, - 7 V and - 12 V power supply voltages. These voltages must be established prior to analog or digital troubleshooting. If power supply voltages are not present on a battery operated Multimeter, low battery voltage can be responsible. Verify low battery voltage by the procedure of Section III under the paragraph concerning low battery voltage detection. After all power supply voltages have been established, the problem must be isolated to the analog or digital and display section. This is accomplished by moving the ANALOG/DIGITAL ISOLATION JUMPER (located near crystal Y1). Disconnect test point CP from test point COMP and connect CP to test point PL. This action isolates the digital and display section from the analog circuits and provides a simulated zero cross-over pulse to the digital circuits for digital troubleshooting.

7-7. ANALOG TROUBLESHOOTING.

7-8. After the power supply voltages are established, analog troubleshooting should proceed using schematics 1 and 2. Failure symptoms should indicate whether the failure is in the signal conditioning circuits (input attenuator, current shunts, ohms converter and ac–to–dc converter) of schematic 1 or the input amplifier and A–D converter of schematic 2. A total failure (all functions inoperative) indicates the input amplifier or A–D converter of schematic 2 is defective.

7-9. A normal input signal may be applied through the front panel terminals of the instrument and half-splitting techniques applied to the analog circuitry when troubleshooting.

NOTE

If the ACA and DCA functions alone are inoperative, check the 2 A fuse located in the front panel AMPS terminal.

Refer to schematic notes and voltages for additional information when troubleshooting a particular circuit area.

7-10. DIGITAL TROUBLESHOOTING.

CAUTION

This instrument contains CMOS digital IC's and, therefore, is highly susceptible to failure due to static discharge. Extra handling precautions should be used when servicing circuit areas containing these devices.

7-11. The need for digital troubleshooting is indicated by the failure of one or more of the following verification steps. The verification steps are divided into four areas:

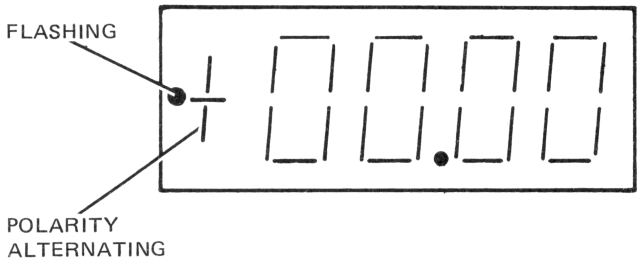
1. Polarity, zero detect and clock circuit verification.
2. Analog switch lines/control state counter verification.
3. Data accumulator input/output verification.
4. Display and display driver verification.

The procedure for checking the verification steps is

initiated by establishment of all power supply voltages and placement of the ANALOG/DIGITAL ISOLATION JUMPER from test point CP to test point PL. Place the front panel controls in the following positions:

POWER ..... ON
FUNCTION ..... DC Volts
RANGE ..... 100 m

7-12. The first indication that the digital and display section is functioning properly will be a front panel display of



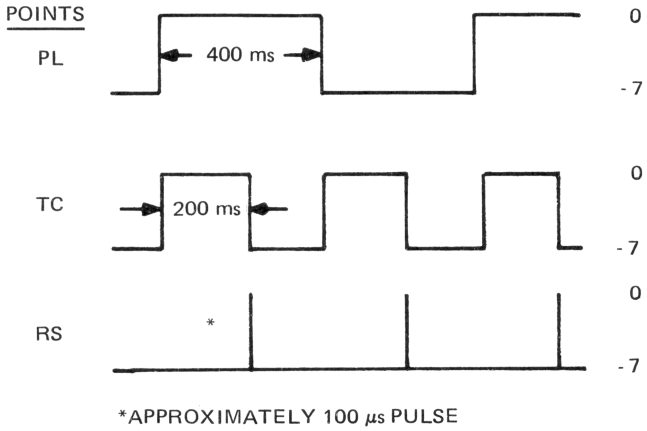
with the sample rate indicator flashing and the plus/minus indicator alternating at a 1.25 Hz rate. In the event that this verification or any of the following verifications fail, normal digital troubleshooting techniques in conjunction with schematic 3 should be used to isolate and correct the failure.

7-13. Polarity, Zero Detect and Clock Circuit Verification.

7-14. Maintain the ANALOG/DIGITAL ISOLATION JUMPER connection between test points CP and PL with FUNCTION and RANGE settings at DCV and 100 m respectively.

A. Verify the 100 kHz clock at test point CL.

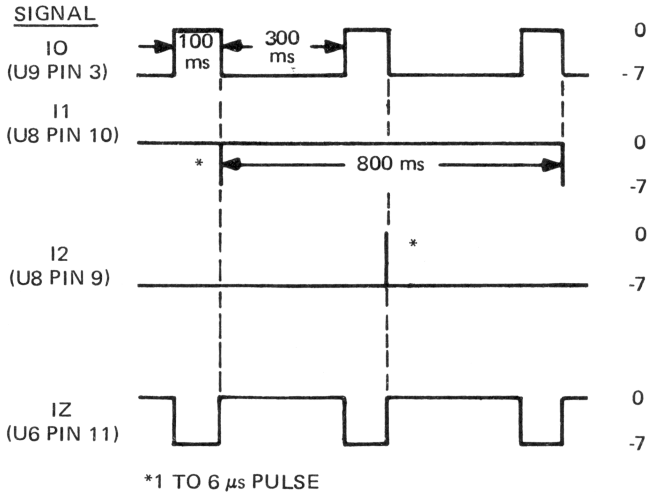
B. Verify the following signals:



If the PL, TC and RS signals are present, the polarity, zero detect and clock circuits are verified.

7-15. Analog Switch Lines and Control State Counter Verification.

7-16. Maintain the ANALOG/DIGITAL ISOLATION JUMPER connection between test points CP and PL with FUNCTION and RANGE settings at DCV and 100 m respectively. Verify the following signals:

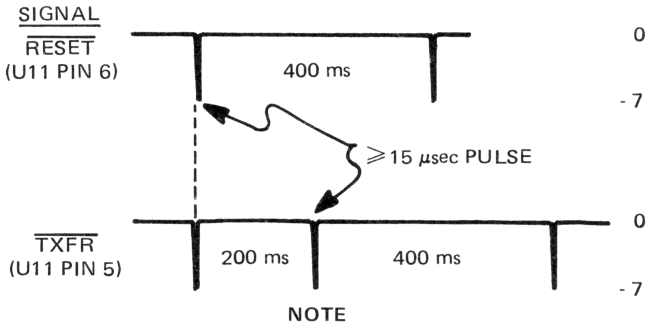


If verification of the IO, I1, I2, and IZ signals is made, the analog switch lines and control state counter are functioning.

7-17. Data Accumulator Input/Output Verification.

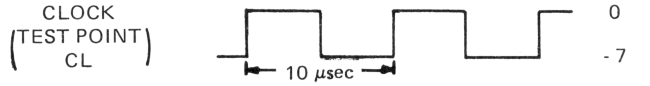
7-18. Maintain the ANALOG/DIGITAL ISOLATION JUMPER connection between test points CP and PL with FUNCTION and RANGE settings at DCV and 100 m respectively. Perform the following steps:

A. Verify the following input signals:



NOTE

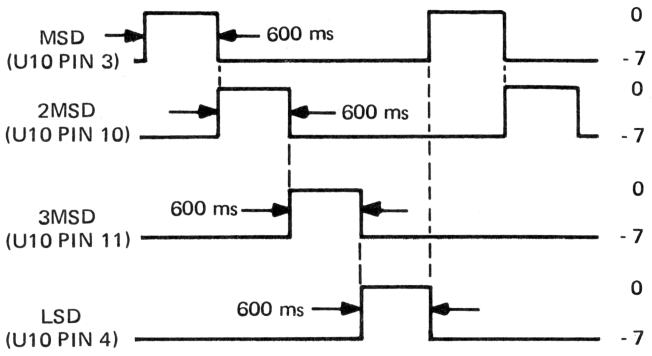
It is essential the clock frequency be verified. An incorrect clock frequency can make U11 appear defective.



B. Verify the following output signals:

1. Connect test point RS to - 7 V and verify COUNT EXTEND output for a 10 microsecond pulse going LOW (- 7 V) at A1U6 pin 10 every 0.1 seconds.

2. Remove jumper between test point RS and - 7 V. Verify MSD, 2MSD, 3MSD and LSD drive lines from A1U10 as follows:



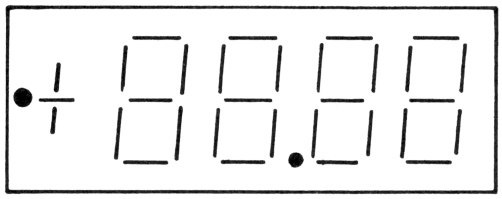
7-19. Display and Display Driver Verification.

7-20. There are two display driver and display verification tests that can be performed. One can be implemented from the A1 board as a quick check and the other can be used for troubleshooting and is accessed from the A2 display interface board. For both tests, maintain the ANALOG/DIGITAL ISOLATION JUMPER connection between test points CP and PL with FUNCTION and RANGE settings at DCV and 100 m respectively.

7-21. Display and Display Driver Quick Test. This verification test is a quick method to test the display and display driver and is implemented from the A1 board.

A. Apply - 7 V to the test point pad DT on the A1 board.

B. Verify the display indication as illustrated below with sample rate indicator flashing and plus/minus indicator alternating.

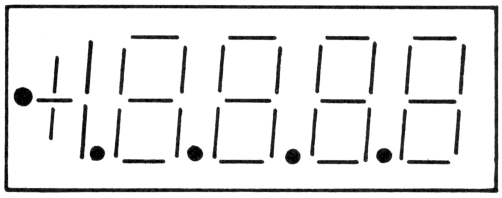


7-22. Display and Display Driver Verification and Troubleshooting Test. This test should be performed in addition to the quick test to check the display and display driver. The test is also used for troubleshooting between the display driver and display LED inputs.

Implement the test as follows:

A. Connect test point – 7 and test point $\overline{LT}$ located on the A2 display interface board.

B. Verify display. If all drivers and LED's are functioning properly, the display will appear as follows:

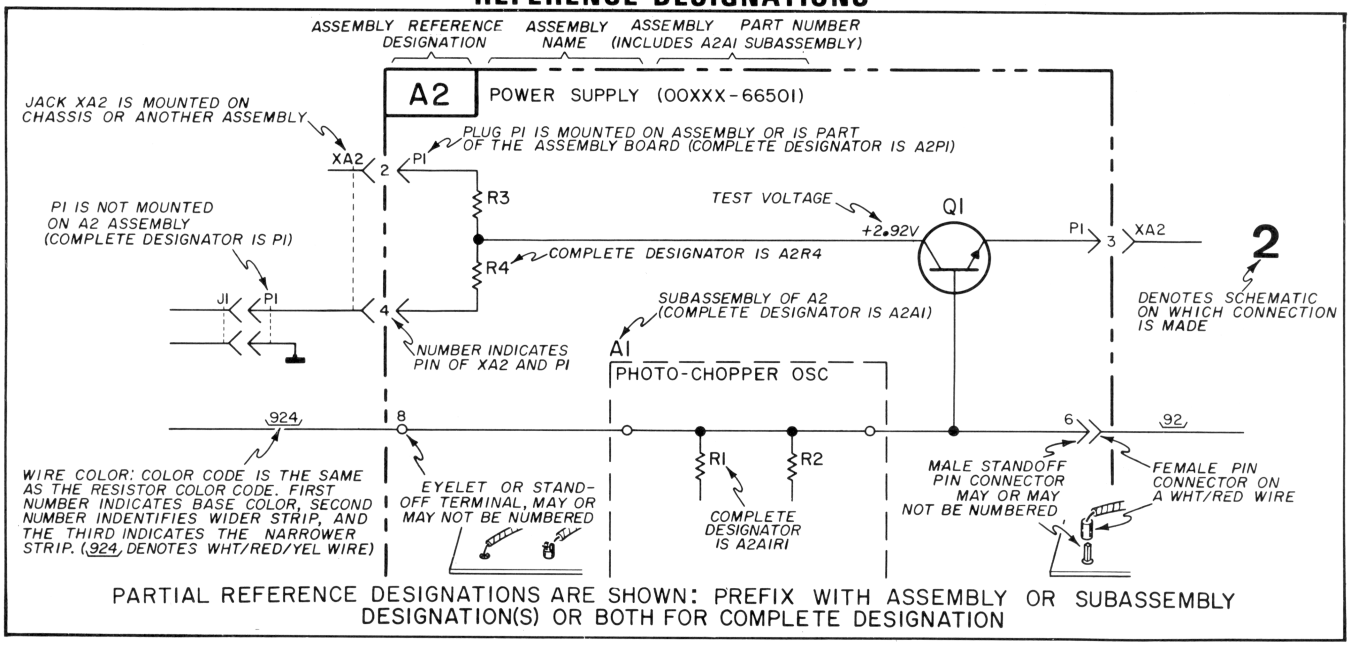


If this display is not realized, the failure can be determined by symptoms and the use of schematic 3.

NOTE

When digital troubleshooting is completed, return the ANALOG/DIGITAL ISOLATION JUMPER to its original position (connect test point COMP to CP).

REFERENCE DESIGNATIONS


ASSEMBLY REFERENCE DESIGNATION
ASSEMBLY NAME
ASSEMBLY PART NUMBER (INCLUDES A2A1 SUBASSEMBLY)
A2
POWER SUPPLY (00XXX-66501)
JACK XA2 IS MOUNTED ON CHASSIS OR ANOTHER ASSEMBLY
XA2
PLUG P1 IS MOUNTED ON ASSEMBLY OR IS PART OF THE ASSEMBLY BOARD (COMPLETE DESIGNATOR IS A2P1)
P1
2
R3
TEST VOLTAGE
+2.92V
Q1
P1 IS NOT MOUNTED ON A2 ASSEMBLY (COMPLETE DESIGNATOR IS P1)
R4
COMPLETE DESIGNATOR IS A2R4
3
XA2
2
DENOTES SCHEMATIC ON WHICH CONNECTION IS MADE
J1
P1
4
SUBASSEMBLY OF A2 (COMPLETE DESIGNATOR IS A2A1)
NUMBER INDICATES PIN OF XA2 AND P1
A1
PHOTO-CHOPPER OSC
924
8
6
92
WIRE COLOR: COLOR CODE IS THE SAME AS THE RESISTOR COLOR CODE. FIRST NUMBER INDICATES BASE COLOR, SECOND NUMBER INDENTIFIES WIDER STRIP, AND THE THIRD INDICATES THE NARROWER STRIP. (924 DENOTES WHT/RED/YEL WIRE)
EYELET OR STAND-OFF TERMINAL, MAY OR MAY NOT BE NUMBERED
R1
R2
COMPLETE DESIGNATOR IS A2A1R1
MALE STANDOFF PIN CONNECTOR MAY OR MAY NOT BE NUMBERED
FEMALE PIN CONNECTOR ON A WHT/RED WIRE
PARTIAL REFERENCE DESIGNATIONS ARE SHOWN: PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION

GENERAL SCHEMATIC NOTES

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION.

2. COMPONENT VALUES ARE SHOWN AS FOLLOWS UNLESS OTHERWISE NOTED.
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
   INDUCTANCE IN MILLIHENRYS

3. DENOTES FRAME OR SHIELD GROUND. USED FOR TERMINALS WHICH ARE PERMANENTLY CONNECTED WITHIN APPROXIMATELY 0.1 OHM OF EARTH GROUND.

DENOTES GROUND ON PRINTED CIRCUIT ASSEMBLY.

5. DENOTES ASSEMBLY.

6. DENOTES FRONT PANEL MARKING.

7. DENOTES REAR PANEL MARKING.

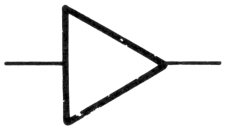
8. DENOTES SCREWDRIVER ADJUST.

9. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY. THE VALUE OF THESE COMPONENTS MAY VARY FROM ONE INSTRUMENT TO ANOTHER.

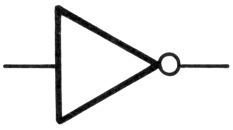
10. DENOTES SECOND APPEARANCE OF A CONNECTOR PIN.

11. 924 DENOTES WIRE COLOR: COLOR CODE SAME AS RESISTOR COLOR CODE. FIRST NUMBER IDENTIFIES BASE COLOR, SECOND NUMBER IDENTIFIES WIDER STRIP, THIRD NUMBER IDENTIFIES NARROWER STRIP. (e.g., 924 = WHITE, RED, YELLOW.)

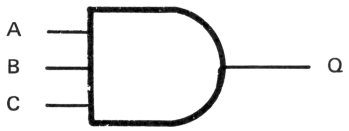
12. DC VOLTAGE LEVELS WERE MEASURED WITH RESPECT TO CIRCUIT GROUND USING A DVM WITH 10 MEGOHM INPUT IMPEDANCE. THE VOLTAGE LEVELS SHOWN ARE NOMINAL AND MAY VARY FROM ONE INSTRUMENT TO ANOTHER DUE TO CHANGE IN TRANSISTOR CHARACTERISTICS. A VARIATION OF ± 10% SHOULD BE ALLOWED.



DENOTES BUFFER

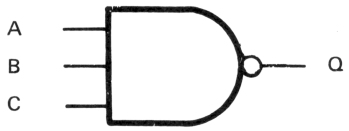


DENOTES INVERTER



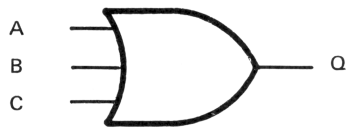
DENOTES AND GATE

A	B	C	Q
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1



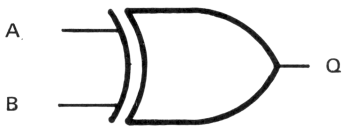
DENOTES NAND GATE

A	B	C	Q
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0



DENOTES NOR GATE

A	B	C	Q
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0



DENOTES EXCLUSIVE OR GATE

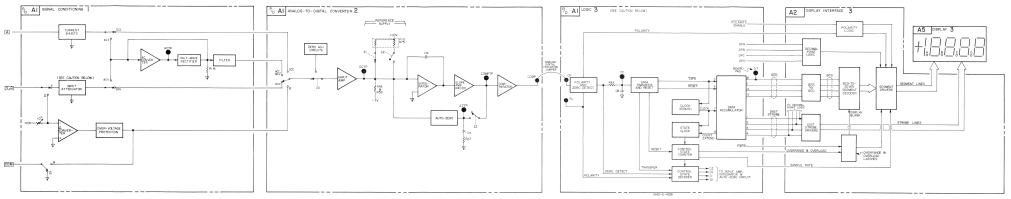
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

FUNCTIONAL BLOCK DIAGRAM NOTES

1. FUNCTIONAL BLOCK DIAGRAM SHOWN IN DCV FUNCTION DURING RUN-UP INTERVAL OF MEASUREMENT SEQUENCE.

2. ASSEMBLY DESIGNATION | SCHEMATIC TITLE | DETAILED SCHEMATIC NUMBER

A3A1	SIGNAL CONDITIONING	1



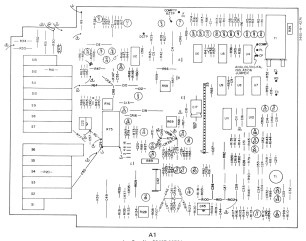
CAUTION

AVOID ATTENUATION PATH REPAIRS PREVIOUS MEASURE AND ZERO MAY BE VERY TIME OF DAY DEPENDENT. IF ANY ATTENUATION PATH REPAIRS ARE MADE, THE ENTIRE ATTENUATION PATH MUST BE RE-CALIBRATED AS A UNIT. IN ADDITION, IF ANY ATTENUATION PATH REPAIRS ARE MADE, ALL OTHER ATTENUATION PATHS MUST BE RE-CALIBRATED TO THE NEW ATTENUATION PATH TO MAINTAIN PROPER RATIOS.

CAUTION

THIS ASSEMBLY CONTAINS CMOS DEVICES. ESD AND HANDLING IS HIGHLY SUCCESSFUL TO FOLLOW ESD PRECAUTIONS. ESD DAMAGE MAY NOT CAUSE IMMEDIATE FAILURE BUT CAN REDUCE RELIABILITY. ESD DAMAGE MAY SHOW UP AS INTERMITTENT OR ERRATIC ANALOG PERFORMANCE PROBLEMS.

Figure 7-1. Functional Block Diagram.



A3
4p- Part No. 03985-66501

A10
PRECISION RESISTOR PACK
(TOP VIEW)

NOTES

1. SCHEMATIC NO. 1 IS SHOWN IN THE DCV FUNCTION, 1 V RANGE, AN OPERATED SWITCH ON THE A1 ASSEMBLY IS INDICATED ON ALL SCHEMATICS BY THE TERMINAL SLIDE CONNECTING THE RIGHT HALF OF THE TERMINAL SET. THE SWITCH BELOW IS SHOWN OPERATED.

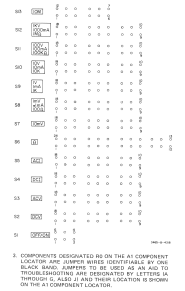
SWITCH NO. SWITCH DESIG. TERMINAL NUMBERS

SXX XXX SXX XXX

FOR EACH SET OF SWITCH TERMINALS, THE SWITCH NO. AND DESIGNATION WILL APPEAR ONCE BUT CAN APPEAR ON EITHER SIDE OF THE TERMINALS.

(SWITCH CONVENTION FOR THE A1046 AND A2047 ASSEMBLIES IS INDICATED BY A NOTE LOCATED ON THE RESPECTIVE SCHEMATICS.)

2. SWITCH TERMINALS ARE NUMBERED IN A COUNTER-CLOCKWISE DIRECTION WHEN VIEWING THE SWITCH BANK FROM THE COMPONENT SIDE (SEE BELOW).



3. COMPONENTS DESIGNATED R0 ON THE A1 COMPONENT LOCATOR ARE JUMPER WIRES IDENTIFIABLE BY ONE BLACK BAND. JUMPERS TO BE USED AS AN AID TO TROUBLESHOOTING ARE DESIGNATED BY LETTERS (A THROUGH G, ALSO J1 AND THEIR LOCATION IS SHOWN ON THE A1 COMPONENT LOCATOR.

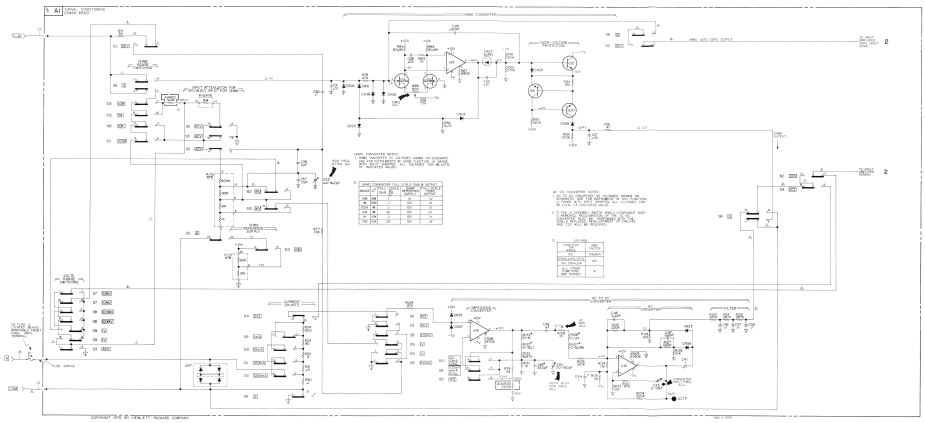


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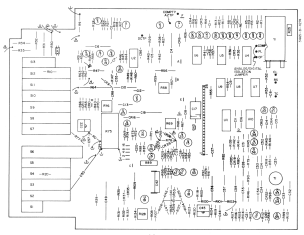
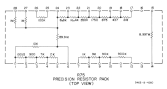
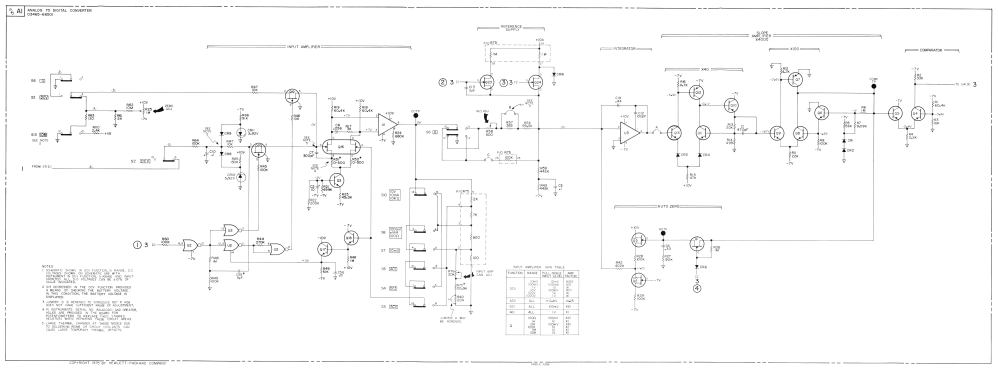
Figure 7-2. Signal Conditioning
7-7/7-8



A1
4pr Part No. 03985-66501



A2A1
PRECISION RESISTOR PACK
(TOP VIEW)


A1
ANALOG-TO-DIGITAL CONVERTER
03440-66501
INPUT AMPLIFIER
INTEGRATOR
AUTOZERO
A/D CONVERTER SPEEDS
A/D
X100
COMPARATOR
AUTO ZERO
NOTES
DIGITAL GROUND IS ISOLATED FROM ANALOG AND EARTH GROUNDS. ANALOG AND EARTH GROUNDS ARE CONNECTED TOGETHER ONLY AT THE POWER SUPPLY.
ALL RESISTORS SHOWN ARE NOMINAL VALUES. ACTUAL VALUES ARE SELECTED AT FACTORY FOR OPTIMUM PERFORMANCE.
ALL CAPACITORS SHOWN ARE NOMINAL VALUES. ACTUAL VALUES ARE SELECTED AT FACTORY FOR OPTIMUM PERFORMANCE.
UNLESS OTHERWISE INDICATED, ALL DIODES ARE 1N4148 OR EQUIVALENT.
UNLESS OTHERWISE INDICATED, ALL TRANSISTORS ARE 2N4416 OR EQUIVALENT.
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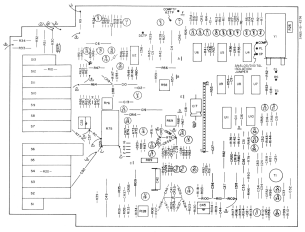
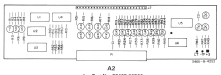
2

Figure 7-3. Analog-to-Digital Converter.
7/9/7/10



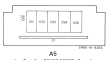
A1

-hp- Part No. 03468-66501



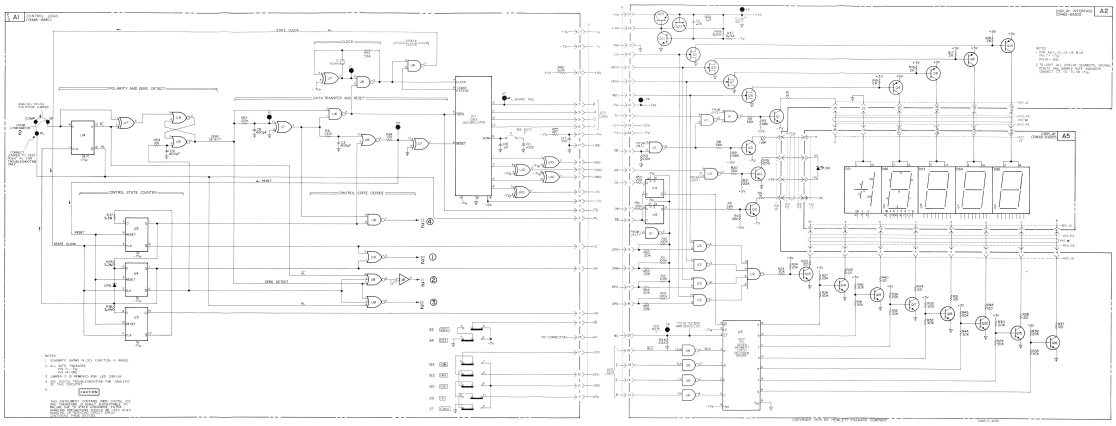
A2

-hp- Part No. 03468-66502



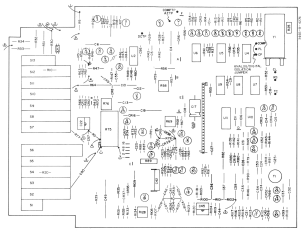
A5

-hp- Part No. 03468-66505, Rev. A

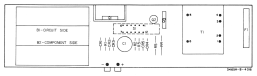


3

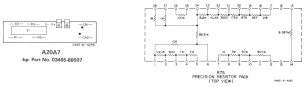
Figure 7-4. Logic and Display
7-11/7-12



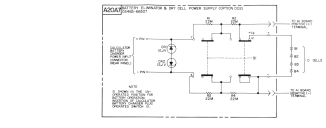
A1
hp Part No. 03465-66501

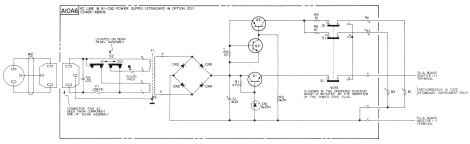


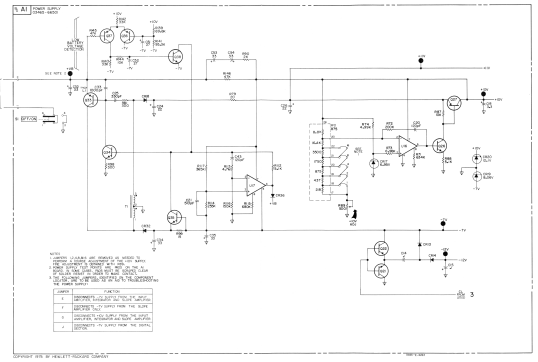
A10A6
hp Part No. 03465-66906



A20A7
hp Part No. 03465-66507







SECTION VIII
BACKDATING

8-1. INTRODUCTION.

8-2. This section contains backdating information which adapts this manual to instruments with serial numbers lower than that shown on the title page.

8-3. CHANGE SEQUENCE.

8-4. Changes are listed in the serial number order that they occurred in the manufacture of the instrument. However, in adapting this manual to an instrument with a particular serial number, apply the changes in reverse order. That is, begin with the latest change and progress to the earliest change applying to that serial number. Table 8-1 lists the serial numbers to which each change applies.

8-5. PARTS NOT INCLUDED IN BACKDATING.

8-6. When replacing a part whose value or part number differs from the schematic diagram or parts list in this manual, yet is not listed in the following changes, use the replacement part number shown in the replaceable parts list of Section VI.

Table 8-1. Manual Backdating Changes.

Instrument Serial Number	Make Manual Changes
1521A00101 thru 1521A00200	1 thru 4
1521A00255 and below except suffix: -00211, -00212, -00215, -00220, -00227, -00230, -00237, -00240, -00244 and -00245	2 thru 4
1521A00201 thru 1521A00400	3, 4
1521A01500 and below	4

CHANGE 1:

Section V. Replace Paragraphs 5-33, 5-34 and 5-39 with the following paragraphs. These paragraphs provide procedures for adjustments using fixed value resistors as opposed to potentiometers listed in Section VI.

5-33. Input Amplifier Gain Adjustment (R76*). This adjustment is required if A1R75, Q16 or U1 is replaced. A DC Standard and a 66.5 kΩ ± 1% resistor (-hp- Part No. 0698-4503) are required for this adjustment.

a. Install a 66.5 kΩ ± 1% resistor in place of R76*.

b. Set the Multimeter function to DCV (⎓ V) and range to 10 m.

c. Connect a short across the input terminals (VΩ and COM) and adjust the Multimeter display for 0.000 with R25 (rear panel ZERO ADJ).

d. Remove short from input terminals and apply +10 mV to the input terminals from the DC Standard.

e. Record the Multimeter maximum display reading for use in next step.

f. Locate the maximum display reading in Table 5-9 and note the corresponding value of R-parallel (R76*).

g. Replace the R76* 66.5 kΩ test resistor with R-parallel (R76*) -hp- part number obtained from Table 5-9.

Table 5-9. R76* Selection.

Multimeter maximum display reading	R-Parallel (R76*)	-hp- Part Number
9.993	44.2 kΩ	0698-4207
9.994	46.4 kΩ	0698-3162
9.995	48.7 kΩ	0698-4497
9.996	52.3 kΩ	0757-0272
9.997	54.9 kΩ	0698-4499
9.998	57.6 kΩ	0698-4500
9.999	60.4 kΩ	0698-3572
10.000	66.5 kΩ	0698-4503
10.001	69.8 kΩ	0698-4504
10.002	75 kΩ	0757-0462
10.003	82.5 kΩ	0757-0463
10.004	90.9 kΩ	0757-0464
10.005	100 kΩ	0757-0465
10.006	110 kΩ	0757-0466
10.007	121 kΩ	0757-0467

5-34. Input Amplifier Balance Adjustment (R50* and R51*).

NOTE

This adjustment does not need to be performed unless A1Q16, A1U1 or A1R75 have been replaced.

A Digital Voltmeter, a decade resistor box and a 100 Ω ± 1% resistor (-hp- Part No. 0698-7320) are required for this adjustment.

a. Install the 100 Ω ± 1% resistor in the R51* position.

b. Connect the decade resistor box in the R50* position minimizing interconnection lead length.

c. Set Multimeter function to DCV (⎓ V) and range to 1 V.

d. Connect ground to the gate of A1Q16 at the junction of A1C7.

e. Connect the Digital Voltmeter to DCTP.

f. Adjust the decade resistor box for a Digital Voltmeter reading at DCTP of 0.5 mV.

g. Change Multimeter range to 100 m.

h. Verify a Digital Voltmeter reading of less than 10 mV at DCTP. If this reading is verified, go to Step j. If this reading is not realized, adjust the decade box to achieve less than 10 mV at DCTP and go to Step i.

i. Change Multimeter range to 1 V. Perform Steps f, g and h until Digital Voltmeter readings specified in these steps are attained.

j. Note the decade resistor box value required to obtain the preceeding adjustment sequence.

k. Select the resistor and -hp- Part No. of the value nearest the decade resistor box value from the "R107* and R108* Padding List" located in the A1 Assembly Miscellaneous Parts of Table 6-3.

l. Remove the decade resistor box and the Digital Voltmeter. Install the selected padding list resistor in the R50* position.

5-39. AC–DC Converter X10 Gain Adjustment (R133* and R134*). A Digital Voltmeter with 5-digit resolution, a DC Standard and a 30 Ω ± 1% resistor, -hp- Part No. 0757-0388 are required for this adjustment.

a. Install the 30 Ω ± 1% test resistor in place of R133* and R134*

b. Set Multimeter function to ACV (~ V) and range to 100 m.

c. Short the input terminals (VΩ and COM).

d. Measure and record the dc voltage at U19 pin 6. Designate this voltage V_1.

e. Apply + 0.5 V dc to the input terminals with the DC Standard.

f. Measure and record the dc voltage at U19 pin 6. Designate this voltage V_2.

g. Calculate and record the gain constant (GAIN CONST.):

$$\text{GAIN CONST.} = \frac{V_2 - V_1}{0.5}$$

h. Calculate and record the R133*, R134* resistance total:

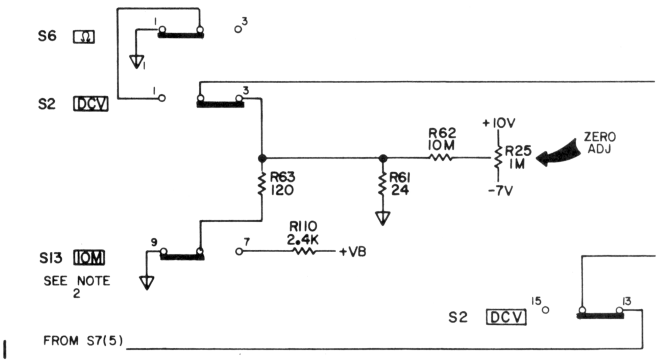
$$(R133^* + R134^*) = (30)\left(\frac{10}{\text{GAIN CONST.}} - 1\right)(10^4)$$

i. Select a resistance combination for R133* and R134* nearest the (R133* + R134*) calculated value from the R107*, R108*, R133* and R134* Padding List located in the miscellaneous parts list of Section VI. Install the selected values.

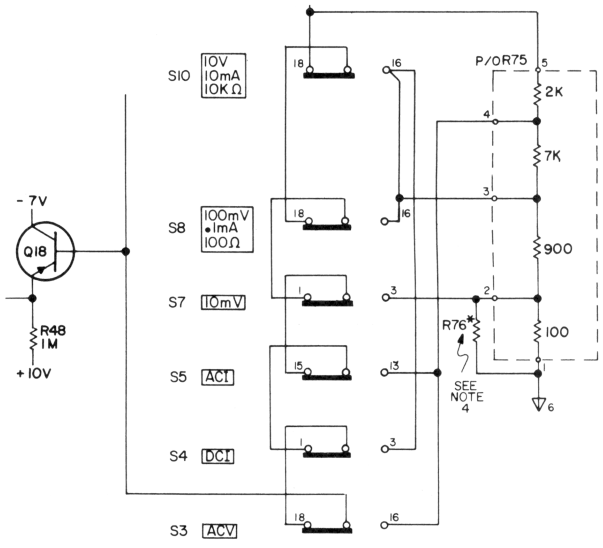
Replace Figure 7-2 (Schematic 1) with backdated Figure 8-1 (Schematic 1).

Table 6-3, Replaceable Parts. Delete A1C30 and A1R70*. Change A1R76* to Part No. 2100-3214, R-Var, 100kilohm. Delete the R70* Padding List under A1 Assembly Miscellaneous Parts.

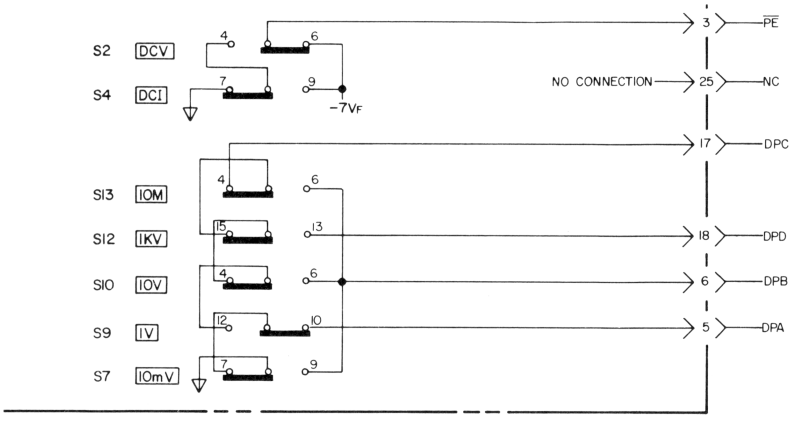
Page 7-9/7-10, Figure 7-3, Schematic No. 2. Make the following switch terminal changes:



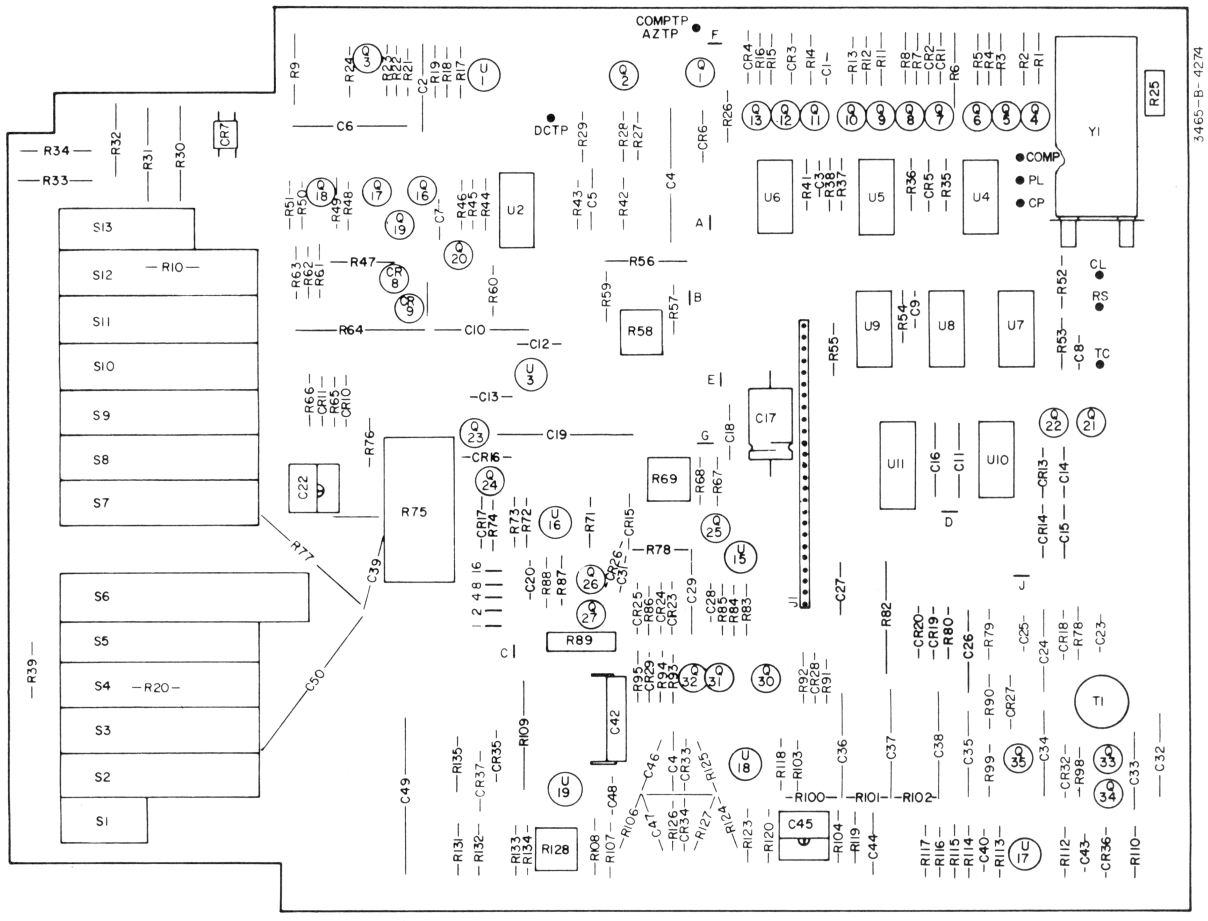
Make the following switch terminal changes, delete R70* and change R76 to a starred value of 66.5 K:



Page 7-11/7-12, Figure 7-4, Schematic No. 3. Make the following switch terminal changes in the decimal point switching:



Pages 7-9 through 7-14. Replace the A1 component locator with the following:



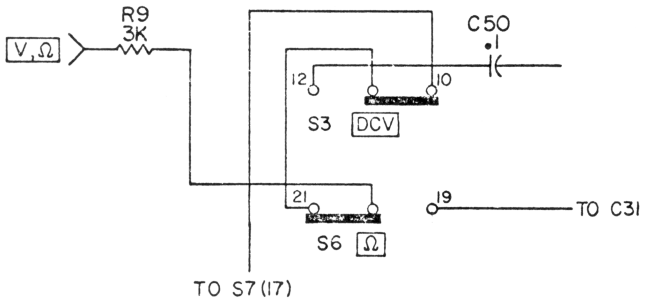
A1

-hp- Part No. 03465-66501

(For Serial Numbers 1521A00101 thru 1521A00200)

CHANGE 2:

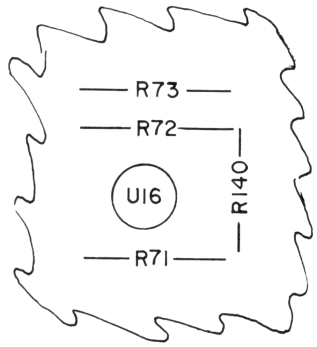
Page 7-7/7-8, Figure 7-2, Schematic No. 1. The portion of input switching involving A1R9 is assembled as shown in the following diagram. This switching should be changed to agree with the corresponding portion as shown in Schematic No. 1 of Section VII.



CHANGE 3:

Section VI, Table 6-3, Replaceable Parts. Add R140 -hp- Part No. 0698-4530, R: fxd 232 K ± 1%. Change Part No. of A1R75, Fine Line Assy, to 1810-0228.

Section VII, Figure 7-5. Add resistor R140 (232 K) connected between R75 pins 23 and 24 in the + 10 V regulator circuit of the power supply. Location of R140 on the A1 Assembly Component Locator is as follows:



Part of A1
Component Locator

CHANGE 4:

Section III, Page 3-1. Delete paragraph heading 3-9 and paragraph text 3-10.

Section IV, Page 4-11. Delete Paragraph heading 4-82 and paragraph text 4-83.

Page 5-7, Add Power Supply Zener Reference Current Adjustment (R74*) preceding the Power Supply + 10 V Reference Voltage Adjustment.

5-28. Power Supply Zener Reference Current Adjustment (R74*).

NOTE

The Power Supply Zener Current Adjustment (R74) should be performed* **only if** *A1CR17 has been replaced.*

If A1CR17 is changed, R74* should be selected and installed prior to adjusting the + 10 V reference voltage. A Digital Voltmeter is required for this adjustment.

a. Maintain existing R74* in circuit (+ 10 V regulator adjustment jumpers 1, 2, 4, 8 and 16 are not to be changed from previous adjustment).

b. Apply power to the Multimeter.

c. Verify the power supply is operating correctly by checking the following voltages:

1. - 7 V Supply Voltage = $-\frac{7}{10}$ x + 10 V Supply Voltage

2. + 11 V Supply Voltage ≅ - 1.5 x - 7 V Supply Voltage

3. (+ 11 V Supply Voltage) - (+ 10 V Supply Voltage) ≅ 0.8 V

d. Measure and record the voltage across A1CR17.

e. Calculate and record the value of R74*:

$$R74^* = \frac{10 - V_{CR17}}{500\ \mu A}$$

f. Select the resistor and part number of the value nearest to that calculated in the previous step from the R74* Padding List located in the A1 Assembly Miscellaneous Parts List of Section VI. Replace R74* if required.

Page 5-8, Paragraph 5-29 Step e. Change A1CR17 zener voltage to 6.4 V ± 5%.

Page 5-9, Table 5-8. Replace table and Notes 1 and 2 with the following:

Table 5-8. Power Supply Jumpers.

READING		POWER SUPPLY JUMPER				
LO	HI	16	8	4	2	1
NOTE 1	.8839	0	0	0	0	0
.8840	.8866	0	0	0	0	1
.8867	.8893	0	0	0	1	0
.8894	.8920	0	0	0	1	1
.8921	.8948	0	0	1	0	0
.8949	.8977	0	0	1	0	1
.8978	.9006	0	0	1	1	0
.9007	.9036	0	0	1	1	1
.9037	.9066	0	1	0	0	0
.9067	.9097	0	1	0	0	1
.9098	.9128	0	1	0	1	0
.9129	.9160	0	1	0	1	1
.9161	.9193	0	1	1	0	0
.9194	.9227	0	1	1	0	1
.9228	.9261	0	1	1	1	0
.9262	.9296	0	1	1	1	1
.9297	.9331	1	0	0	0	0
.9332	.9368	1	0	0	0	1
.9369	.9405	1	0	0	1	0
.9406	.9443	1	0	0	1	1
.9444	.9482	1	0	1	0	0
.9483	.9521	1	0	1	0	1
.9522	.9562	1	0	1	1	0
.9563	.9604	1	0	1	1	1
.9605	.9646	1	1	0	0	0
.9647	.9690	1	1	0	0	1
.9691	.9734	1	1	0	1	0
.9735	.9780	1	1	0	1	1
.9781	.9827	1	1	1	0	0
.9828	.9874	1	1	1	0	1
.9875	.9924	1	1	1	1	0
.9925	NOTE 2	1	1	1	1	1

"0" = Remove Jumper
"1" = Leave Jumper In Place

NOTE 1. For Readings less than .8788, adjustment cannot be made. Check A1CR17 zener voltage for 6.4 V ± 5%, A1R75 and A1U16.

NOTE 2. Adjustment cannot be made for readings greater than 1.0000. Check A1CR17 for 6.4 V ± 5%, A1R75 and A1U16.

Section VI, Table 6-3. Change A1CR17 to Part No. 1902-0649, Diode-Znr 1N4567 6.4 V 5%. Change A1R72 to Part No. 0698-4531, Res 267 K 1% .125W. Change A1R73 to Part No. 0698-3498, Res 8.66 K 1% .125W. Change A1R74 to a starred value (A1R74*) with the following padding list:

R74*, PADDING LIST FOR R74*

0698-3226, R:Fxd Met Flm 6.49 K Ohm 1% 1/8W, 28480, 0698-3226
0698-3484, R:Fxd Met Flm 6.65 K Ohm 1% 1/8W, 28480, 0698-3484
0757-0439, R:Fxd Met Flm 6.81 K Ohm 1% 1/8W, 28480, 0757-0439
0698-4470, R:Fxd Met Flm 6.98 K Ohm 1% 1/8W, 28480, 0698-4470
0698-4471, R:Fxd Met Flm 7.15 K Ohm 1% 1/8W, 28480, 0698-4471
0698-3518, R:Fxd Met Flm 7.32 K Ohm 1% 1/8W, 28480, 0698-3518
0757-0440, R:Fxd Met Flm 7.50 K Ohm 1% 1/8W, 28480, 0757-0440
0698-4472, R:Fxd Met Flm 7.68 K Ohm 1% 1/8W, 28480, 0698-4472
0698-3259, R:Fxd Met Flm 7.87 K Ohm 1% 1/8W, 28480, 0698-3259

Change A1R75 to Part No. 1810-0239.

Section VI, Table 6-3. Add A1CR27, Part No. 1901-0040, Diode-Switching 2NS 30 V 50 mA. Change A1R90 to 0683-3015, Res 300 5% .25W. Delete A1C51 through A1C56, A1CR38, A1CR39, A1Q36, A1Q37, A1Q38, A1R139, A1R141 through A1R149, A2C2 and A2R50 through A2R55.

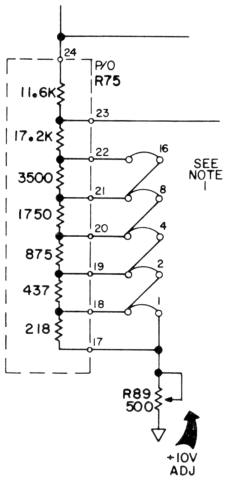
Section VII, Page 7-1. Delete from Paragraph 7-6 the following sentences: "If power supply voltages are not present on a battery operated Multimeter, low battery voltage can be responsible. Verify low battery voltage by the procedure of Section III under the paragraph concerning low battery voltage detection."

Page 7-7/7-8, Figure 7-2. Delete A1CR38 and CR39 from the ohms converter.

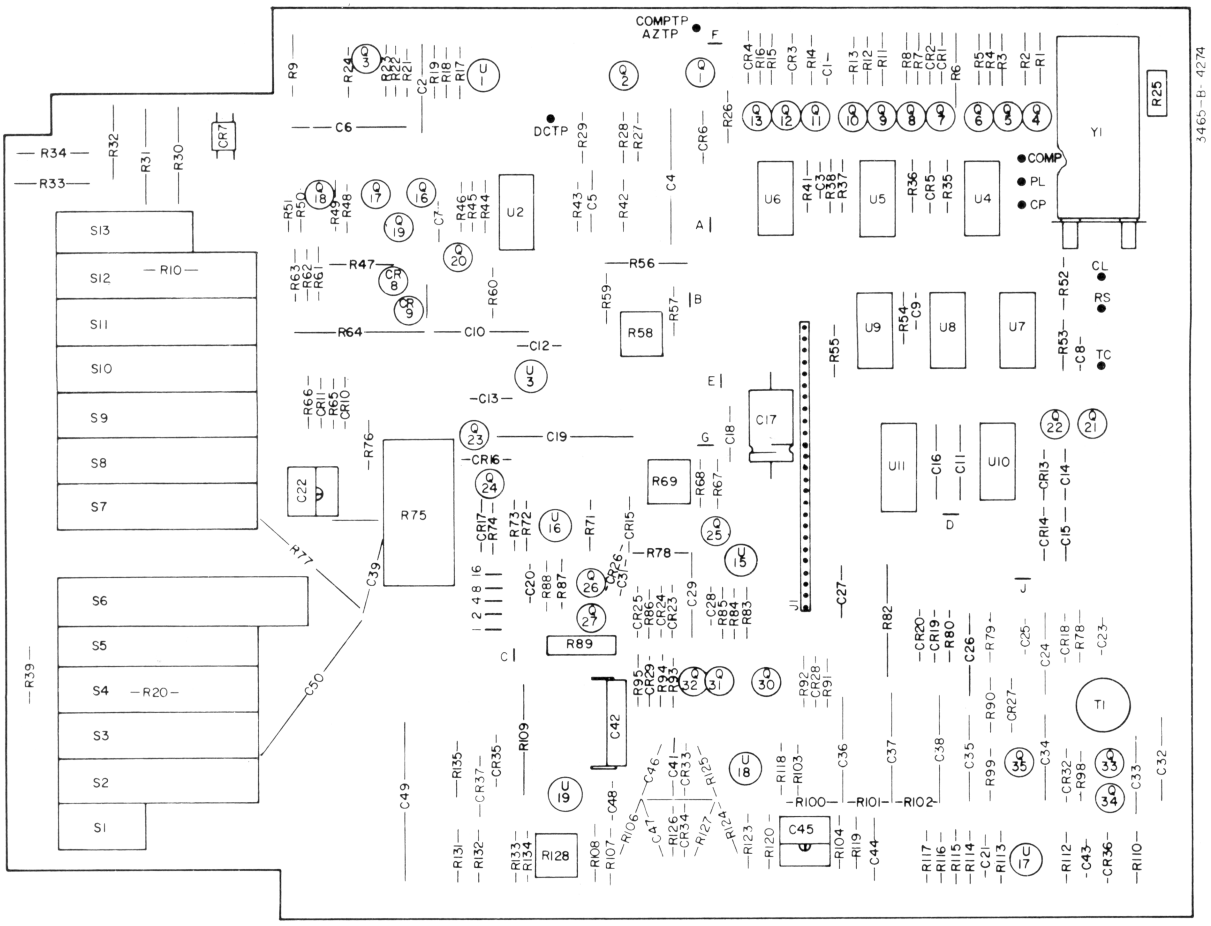
Page 7-9/7-10, Figure 7-3. Replace A1R147 with a short. Delete A1C55, A1C56, A1R148 and A1R149.

Page 7-11/7-12, Figure 7-4. Delete A2R50 through A2R55 and make direct connections.

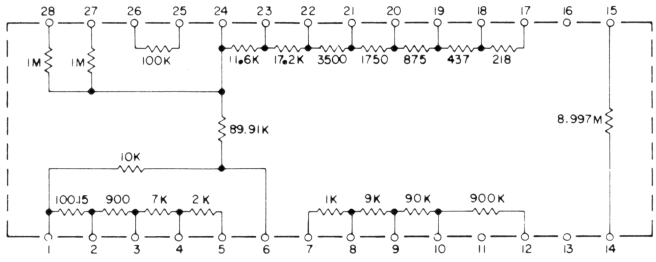
Page 7-13/7-14, Figure 7-5. Change value of A1R90 to 300 ohms. Replace the combination of A1C53 and C54 with A1CR27, anode to + VB, cathode to A1R90. Delete A1C51, C52, A1Q36, Q37 and Q38, A1R139, A1R141 through R146 and A2C2. Change CR17 voltage to 6.4 V. Change R72 to 267 K, R73 to 8.68 K, and R74 to a starred value (R74*). Change Part No. of R75 to 1810-0239 and change values of p/o R75 as shown below:



Pages 7-9 through 7-14. Replace the A1 component locator and top view of R75, Precision Resistor Pack, with the following diagrams.



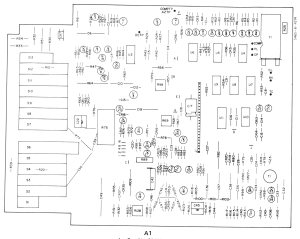
A1
-hp- Part No. 03465-66501
For Serial Numbers 1521A00201 thru 1521A01500



R75
PRECISION RESISTOR PACK
(TOP VIEW)

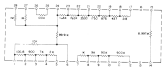
3465-B-4260

-hp- Part No. 1810-0239



A1

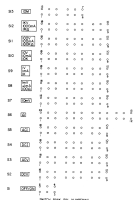
Ap- Part No. 03489-66501



A10

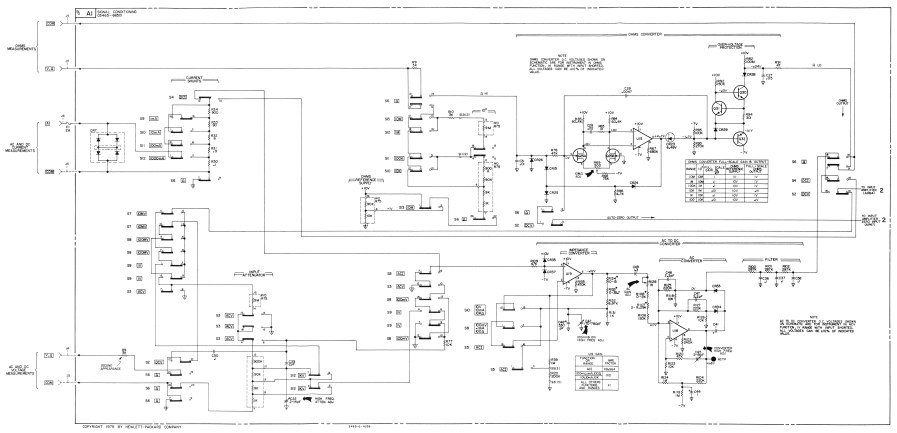
PRECISION RESISTOR PACK

(TOP VIEW)



SWITCH BANK P/N 1LAMINNING

COMPONENT SIDE?



A1 SIGNAL CONDITIONING CHASSIS ABOVE

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1

Figure 8-1. Signal Conditioning.

MANUAL CHANGES

MODEL 3465A

MULTIMETER

Manual Part No. 03465-90004

▌ New or Revised Item

ERRATA

Page 1-1, Paragraph 1-16. Change item 5 to "Model 11173A Handle Kit (Rack).

Page 5-0, Table 5-1. Change value in required characteristics column for resistor part no. 0698-5049 (last resistor in the table) to 10 M, ± 1%.

Page 5-9, Paragraph 5-36, Step i. Within parenthesis in formula for (R107* + R108*), replace the number 0.9995 with 0.9966.

Page 6-3, Table 6-3. Add diodes A1CR1 through A1CR6 to the parts list as follows:

A1CR1, CR2, 1901-0040, 13, Diode-Switching, 28480, 1901-0040
A1CR3, CR4, 1901-0518, 4, Diode-Schottky, 28480, 1901-0518
A1CR5, CR6, 1901-0040, Diode-Switching, 28480, 1901-0040

Page 6-4, Table 6-3. Add designations A1L2, A1L3 and A1L4 to the parts list. These components are the same as A1L1, part no. 9170-0894, Core-Shielding Bead.

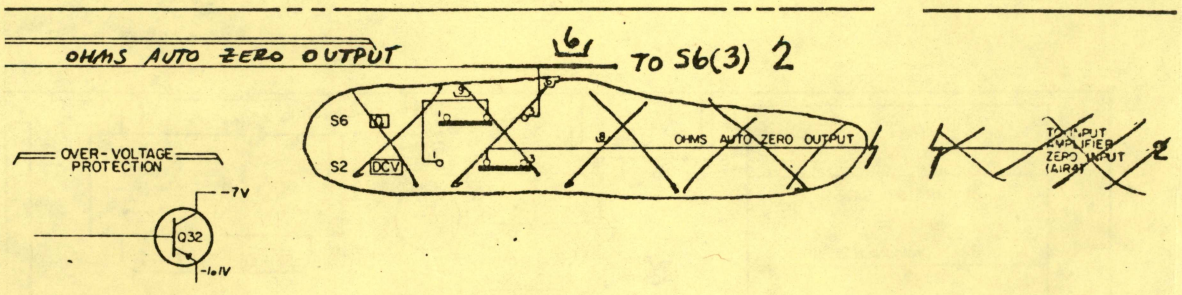
Page 6-5, Table 6-3. Change part no. of the fine line assembly, A1R75, to 1810-0253.

Page 6-7, Table 6-3. Add designation A2L1, part no. 9170-0894, Core-Shielding Bead.

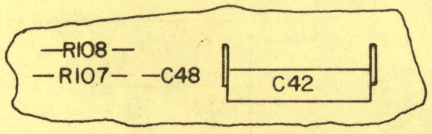
Page 6-8, Table 6-3. Add A10A6C3, part no. 0150-0093, C:fxd .01 μF, 100 V. Change part no. of Transformer, A10A6T1 to 9100-3851. Under A10 Assembly Miscellaneous Parts, add "Battery Clamp" to description of part no. 1460-1426.

Page 6-10, Table 6-3, Mechanical Parts List. Change part no. of MP8a (Rear Panel-Std or Option 001) to 5040-8026. Change part no. of MP18 (Switch Shield) to 03465-60604. This is now a "SWITCH SHIELD ASSEMBLY".

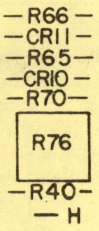
Section VII, Schematic No. 1. Make the following change to the OHMS AUTO ZERO OUTPUT SWITCHING:



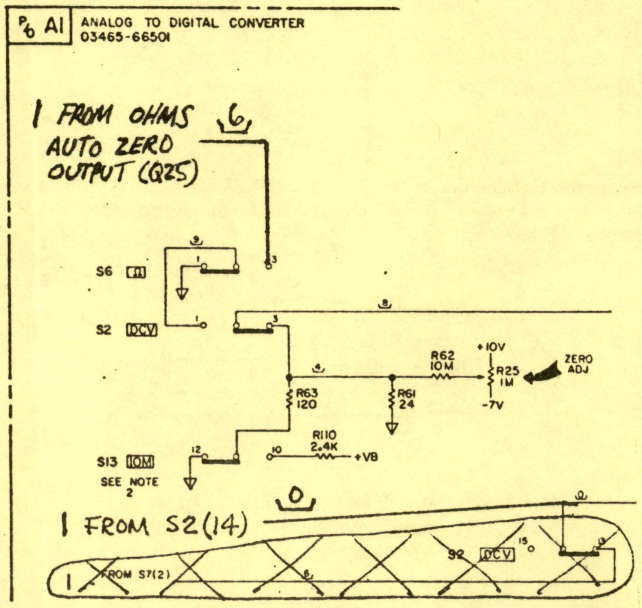
Section VII, Schematics No. 1, 2, 3 and 4. Make the following additions and changses to the A1 component locator. Add capacitor C48 between R107 and C42:



Add Jumper J between C15 and C25 and next to R144. Change the location of R40 and Jumper H as follows:

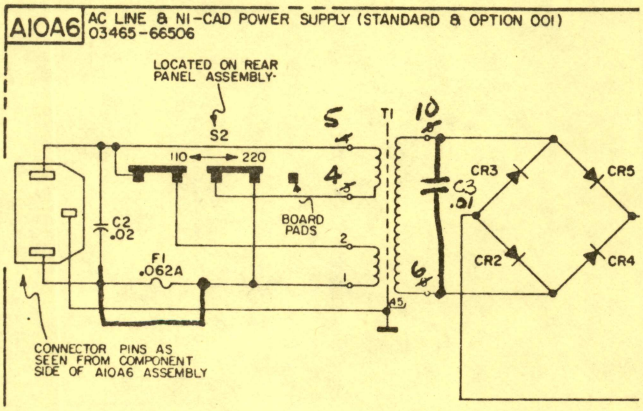


Section VII, Schematic No. 2. Make the following changes to the input amplifier switching:

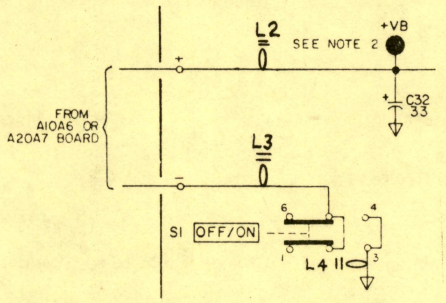


Section VII, Schematic 4. Add shielding bead A2L1 to the emitter of A2Q22 on the Display Interface board.

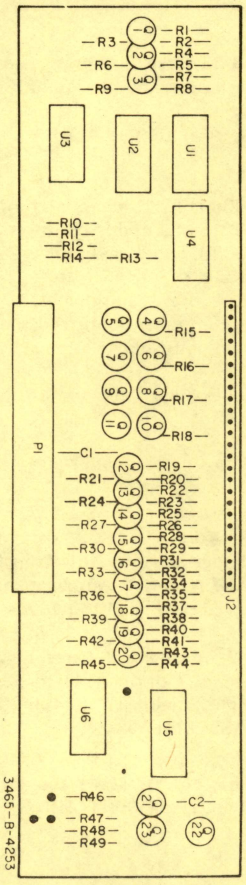
Section VII, Schematic 4. Replace the A10A6 component locator and modify the A10A6 schematic to:
1. Change connection of C2 to other side of Fuse F1.
2. Change pin numbers of transformer T1.
3. Add C3 (see following).



Section VII, Schematic 4. Add shielding beads, A1L2, A1L3 and A1L4 as follows:

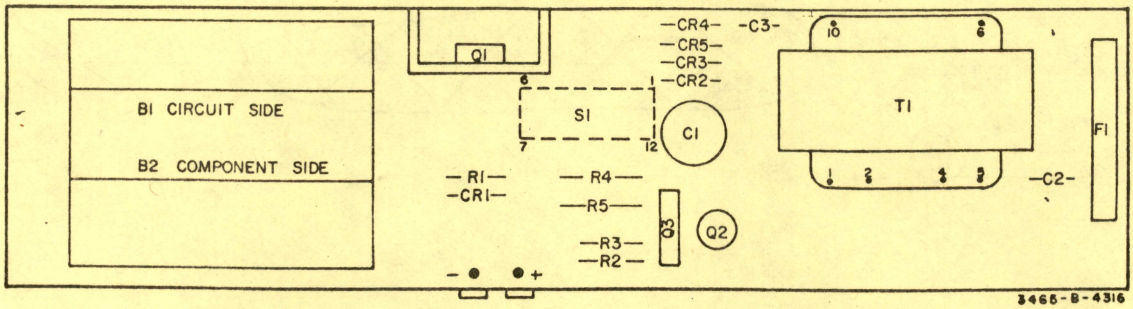


Section VIII, Backdating CHANGE 4. Add the following: "Schematic No. 3, Replace the A2 component locator with the following:



A2

-hp- Part No. 03465-66502, Rev. B



A10A6

-hp- Part No. 03465-66506

ERRATA

Page 3-1, Add to Paragraph 3-10.

NOTE

In protecting batteries and circuitry the low battery voltage dectection circuit may shut down the instrument if

1. *the power switch is momentarily turned off then back on, or*
2. *if a live line power cord is attached to the instrument, while it is operating in the battery mode.*

To restore normal operation the instrument must be turned off for a minimum of 10 seconds.

Page 5-9, Paragraph 5-36(i). Change (0.9995 x CONST-1) to (0.9966 x CONST-1).

Page 5-10, Paragraphs 5-39(c) and 5-40(c). Change ± 100 counts to ± 10 counts.

Page 6-8, Table 6-3. Reference Designation A10A6Q3, -hp- Part No. 1853-0394, Description. Change NPN to PNP.

ERRATA

Page 7-13/7-14, Figure 7-5, Assembly A20A7 Schematic. Add wire connections from pin 4 to 5, and from pin 8 to 9 of S1.

CHANGE NO. 1 applies to S/N 1521A01501 and greater.

Page 7-11/7-12, Figure 7-4, Control Logic Assembly, A1, Schematic. Add capacitor C23, 100 pF from the junction of Y1, R52 and pin 9 of U7 to PC assembly ground.

Page 6-3. Add in sequence Ref. Desig., P/N, Qty and Desc., A1C23, 0150-0073, 1, Capacitor - FXD 100 pF 1000 V.

CHANGE NO. 2 applies to S/N 1546A01701 and greater.

Page 7-11/7-12, Figure 7-4, Control Logic Assembly, A1, Schematic. Delete C11, jumper D and Note 3. Renumber Notes 4 and 5 to 3 and 4 respectively.

Page 7-11, Figure 7-4, Display Interface, A2, Schematic. Delete C2.

Page 6-3. Delete A1C11 and all relevant nomenclature.

Page 6-7. Delete A2C2 and all relevant nomenclature.

CHANGE NO. 3 applies to S/N 1546A02151 and greater.

Page 6-9. Delete Part No. 0363-0108 and all relevant nomenclature. Add Part No. and Description 0380-0578, Standoff.

CHANGE NO. 4 applies to S/N 1546A04401.

Page 6-7. Delete A2Q12, A2R19, A2R20, A2R21 and all relevant nomenclature.

Page 6-8. Delete A5CR1 and all relevant nomenclature.

Page 7-11/7-12, Figure 7-4. Delete R19, R20, R21 and Q12 of the Display Interface, A2, Schematic and CR1 of the Display, A5, Schematic.

CHANGE NO. 5 applies to S/N 1546A01700 and greater.

Page 6-5. Change the Part Number and value of A1R103 from 0683-2445, 240 K to 0683-1245, 120 K.

Page 7-7/7-8, Figure 7-2. Change the value of R103 from 240 K to 120 K.

CHANGE NO. 6 applies to S/N 1546A01701 and greater.

Page 6-3. Change the Part Number and value of A1C39 from 0160-2046, 2 pF ± .5 pF to 0160-999P PAD VALUE. Star the Reference Designations A1C39 and A1C57.